New York State Education Department

NEW YORK STATE MUSEUM

60th ANNUAL REPORT

1906

VOL. 2

APPENDIX 5

TRANSMITTED TO THE LEGISLATURE JUNE 26, 1907

ALBANY
NEW YORK STATE EDUCATION DEPARTMENT
1908

STATE OF NEW YORK

No. 68

IN ASSEMBLY

JUNE 26, 1907

60th ANNUAL REPORT

OF THE

NEW YORK STATE MUSEUM

To the Legislature of the State of New York

We have the honor to submit herewith, pursuant to law, as the 60th Annual Report of the New York State Museum, the report of the Director, including the reports of the State Geologist and State Paleontologist, and the reports of the State Entomologist and the State Botanist, with appendixes.

ST CLAIR MCKELWAY
Vice Chancellor of the University

ANDREW S. DRAPER
Commissioner of Education

Appendix 5

Geology 12, 13, 14

Museum bulletins 107, 111, 115

12 Geological Papers
13 Drumlins of Central Western New York
14 Long Lake Quadrangle

Published monthly by the

New York State Education Department

BULLETIN 401 MAY 1907

New York State Museum

JOHN M. CLARKE, Director

Bulletin 107

GEOLOGY 12

GEOLOGICAL PAPERS

ALBANY

NEW YORK STATE EDUCATION DEPARTMENT

1907

M167m-J16-1500 Price 90 cents

New York State Education Department
Science Division, July 7, 1906

Hon. A. S. Draper LL.D.
Commissioner of Education

My dear sir: I beg to communicate herewith for publication as a bulletin of the State Museum, a series of geological papers by various members of the staff of this division.

Very respectfully yours
John M. Clarke
Director

Approved for publication, July 9, 1906

A. S. Draper
Commissioner of Education

New York State Education Department

New York State Museum

John M. Clarke, Director

Bulletin 107

GEOLOGY 12

GEOLOGICAL PAPERS

POSTGLACIAL FAULTS OF EASTERN NEW YORK

BY

J. B. WOODWORTH

Introduction

While investigating the changes of level which have affected the Pleistocene river and lake deposits of the Hudson and Champlain valleys, the writer noted certain small dislocations of the bed rock which have taken place in the comparatively recent time since the glaciation of the surface. The importance of these fractures as indexes of a rock movement which appears to be associated in time at least with the tilting of the continent in the postglacial epoch led to the following study of the distribution and character of the fractures.

A reference to the literature of the State showed that Mather in the original geological survey of the first district noted the occurrence of postglacial faults on the east side of the Hudson valley. Having first referred to a class of faults much more

frequently seen in the glacial gravels, he makes the following statement in regard to the faults here referred to:

The other class is where the slate rocks on the east side of the Hudson valley had been ground down, smoothed, deeply grooved and scratched across their edges; and since the action that had produced these effects the masses of slate had been shifted a few inches in a vertical direction by a slight fault, so that the grooves and scratches on the *lower* part of the mass were continued quite up to that part that had been elevated; and on the *upper* mass, the same grooves that had been once continuous, were prolonged in their former direction, with the same breadth and depth. This shift of position, or slight fault, must have been subsequent to the period when the scratches were made, or the scratches could not have been continued close up to the vertical surface of the more elevated portion, and without wearing the sharp edge of the slate on the upper portion of the shifted mass. This locality was where the Quaternary had covered it, but the example can not with certainty be referred to that part of the Quarternary period of which we are now speaking; for it may belong to the elevation that took place after the drift period, and preceding the elevation by which the Quaternary deposits were raised to their present level.

The locality and example referred to above, was observed by myself in Copake or Ancram near the north end of Winchell's mountain, and not far from the base of Mount Washington, on the road from Copake to Boston Corners.[1] Professors Merrick and Cassels were present with me, and I called their attention to this, as an important fact for them to observe, in consequence of the kind of evidence thus afforded of the relative periods of time during which the rocks were disturbed in position. Professor Merrick, a few days afterwards, in his explorations, discovered several more localities near each other, about half a mile west of Long Pond in Clinton,[2] where the same facts were observed. I quote his report to me.

An interesting phenomenon may be seen in the rocks about ½ mile west of Long Pond in Clinton. The parts of the rock have changed their relative position since they were worn down by the diluvial action. In two different places, at but a short distance from each other, one part of the rock has been raised, or the other part settled from 2 to 3 inches, the strata being nearly vertical. Five or six similar dislocations, of from half an inch to 1 inch, occur in the immediate vicinity.

Of the dislocation of the rocks since the effects of the diluvial action upon it, there can be no doubt, as the scratches or furrows upon the elevated and depressed parts precisely correspond, and are carried on the latter entirely up to the former, the elevated ridge of which is unmarked or broken (unbroken?). These dis-

[1] This is probably the locality described below on p. 16. *J. B. W.*
[2] I have not yet seen this locality. *J. B. W.*

locations are exposed for 25 or 30 feet; and it should be remarked, that they do not occur in the vicinity of a ledge, a cliff or steep hillside of rocks, or upon the side of a hill, but upon a level surface upon the summit.[1]

Mather[2] also reported another locality east of the Hudson near Hyde Park. He states that

The smoothed and scratched greywacke or grit was observed on the ridge east of Hyde Park; and about half a mile east of the post road opposite to half a mile north of De Graff's Tavern, the grooves and scratches, which were perfectly similar in size, depth and direction, were interrupted by slips or slight faults of the rock since the scratches have been made. Professor Cassels observed them in several places in that vicinity. The edges of the rock, both above and below, on the slip, were sharp, and the grooves and scratches of the lower mass were continuous plump up to the surface of the upper mass; and on the upper mass they were continued quite to the sharp edge along which the slip has taken place.

This type of relatively recent faults appears next to have been seen and described by Mr G. F. Matthew as occurring in a very pronounced manner in the environs of St John, New Brunswick. The Cambric slates of the upper division of the St John group are described by him as being cut by n. e. and s. w. faults, with a hade varying from 60° to 80° s. e. There are also diagonal faults extending north and south, and east and west. In the city of St John, the faults vary in downthrow from ¼ inch to 4 inches, the downthrow with one exception being on the north. In one locality Matthew found the sum of the displacements to be 5 feet 8 inches. He has published a photograph showing the character of the faulted surfaces.[3]

Matthew noted the reversed character of the faults and supposed the movement to be due to a failure of support beneath, or to a lateral thrust from the southeast, with his preference for the latter view, in support of which he cites the ancient mountain-building pressures acting in this direction. He also notes the pressure acting on the rocks at Monson, Mass., reported by Niles, and the occurrence of slight earthquake shocks near St John, N. B., as evidence independent of the faults that the earth's crust in this part of the continent is yielding under strain.

---

[1] Mather, W. W. Geology of New York: Report on First District. 1843. p. 156–57.

[2] *Op. cit.* p. 387. Locality not visited by J. B. W.

[3] Post-glacial Faults of St John, N. B. Am. Jour. Sci. Ser. 3. 1894. 48:501–3, pl. 11. Also Movements of the Earth's Crust at St John, New Brunswick, in Post-glacial Times. N. B. Nat. Hist. Soc. Bul. 12. 1894. p. 34–42.

Another district in this geologic province in which postglacial faults have been described lies along the northern border of Vermont and New Hampshire in southwestern Quebec. Mr R. Chalmers of the Geological Survey of Canada has recently described numerous and yet more pronounced instances of these dislocations in the Cambric and Cambro-Siluric slates of that field, viz, in the southern part of the seigniory of Aubert Gallion; at St Evariste de Forsyth, Beauce county; east of Jersey Mills; near the mouth of Gilbert river, at MacLeod crossing, Canadian Pacific Railroad; east of Scotstown; between Sherbrooke and Stoke Centre, etc. Some of these localities are shown on the accompanying sketch map [pl. 1].

The prevalent downthrows are stated to be toward the north, but throws on the south or southeast occur. Chalmers reports instances of dislocations of from 4 to 6 feet. He states that the faults in this district "seem to have occurred near some ridge or mountain or mass of resisting rocks, the downthrow being usually on the side towards it, or rather the sliding up of the slates has taken place on the side farthest from it."[1]

An instance in New Hampshire noted by Professor Hitchcock is referred to in the following pages.

The above citations show that there is a group of postglacial faults found in the belts of Cambric and Lower Siluric slates over a large area with a dominant upthrow from the southeast.

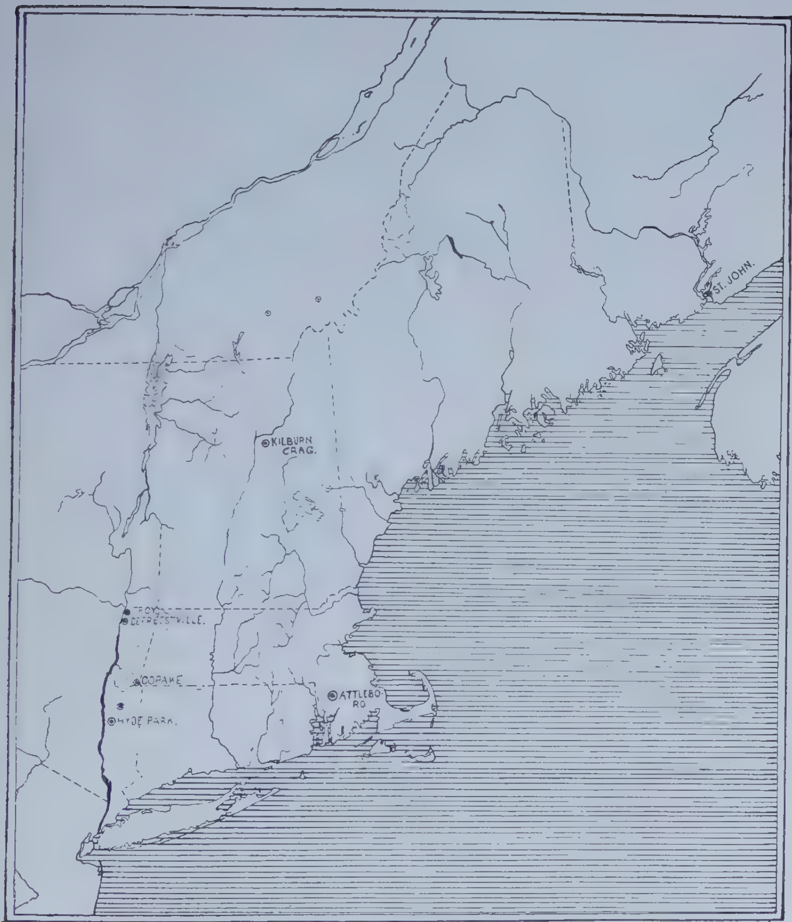
Personal observations

The following notes serve to show the character of the localities cursorily described by Mather and the details of examples recently discovered. The localities which appear not to have been earlier described by others are as follows: South Troy, Rensselaer, Defreestville, and Pumpkin Hollow. The position of these places is indicated by the locality marks on the accompanying sketch map [fig. 1].

Faults in South Troy. An instructive locality of small postglacial faults was to be seen in the summer of 1904 in the southern part of Troy, on the east bank of the Hudson gorge, south of the Poesten kill. At this point the Albany clays have been largely stripped off from the basal portion of the slate wall of

[1]Chalmers, R. Report on the Surface Geology and Auriferous Deposits of South-eastern Quebec. Geol. Sur. Can. An. Rep't. Pt J. 1898. 10:9j–12j.

Plate 1



Map showing localities of postglacial faults in New York, New Brunswick and Quebec. Compiled from Mather, Matthews, Chalmers and maps by J. B. Woodworth, 1904

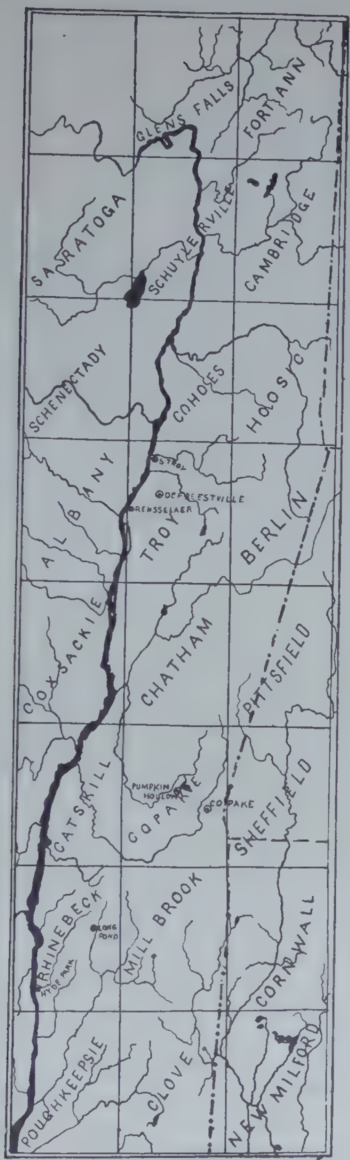


Fig. 1 Sketch map of New York east of the Hudson. The quadrangles with names correspond to the units of the State map. The localities at which postglacial faults have been seen are marked by a dotted circle.

the gorge, and a quarry has been opened north of the end of Munroe street for the purpose of obtaining the sandstone which is here caught in the axis of a complicated synclinal fold bounded

east and west by fragile black shales with a somewhat slaty structure [*see* pl. 2].

Near the base of this slope, or from about 20 to 60 feet above the level of 4th street, the surface of the rock appears in a well glaciated area broken by postglacial faults, or at least by faults which interrupt the glaciated rock surface.

The strike of the sandstones and slates is here 9° east of north, and the glacial striae run up the bank on a course s. 21° e. The dip of the slates is approximately 40° e., where not involved in the abrupt curvatures of the folds.

The faults here referred to occur, so far as my observations go, altogether on the eastern side of the sandstone beds in the axis

Fig. 2 Cross-section of the left bank of the Hudson south of the Poesten kill, in Troy, N. Y. showing position of postglacial faults in relation to river bank

of the syncline. A rough sketch of a portion of the faulted surface is shown in figure 3, in which there is no pretension to accuracy of measurement.

Below the area shown in figure 3, there is an imperfectly shown slip of 6 inches, the greatest throw I have measured in eastern New York. The faults which traverse the area mapped measured, in the order in which they are encountered in ascending the slope, 5, 1, 1.5, and from 2 to 5 inches. Thus within 30 feet measured up the slope there is a drop of 12 inches to the west on these faults. All of the faults observed at this locality are of the reverse type, with a steep dip to the east and a downthrow to the west. With one exception the faults are closely parallel to the steep dip of the stratification of the beds, though it is noticeable that there is a tendency of the fractures to depart from the bedding of the fine, black, fragile, shaly beds. One break extends practically at right angles to the bedding with an uplift on the north [*see* pl. 3]. Two of the fractures shown in the sketch converge southward and die out within the limits of the exposure. The other principal faults are traceable to the edge of the clay deposit. Their full extent in that direction is unknown.

Plate 2

Broken synclinal fold in quarry near end of Munroe street in South Troy; looking south. Photo by J. B. Woodworth.

These faults appear to be limited to the fragile shales or slates lying on the eastern side of the sandstone body above mentioned.

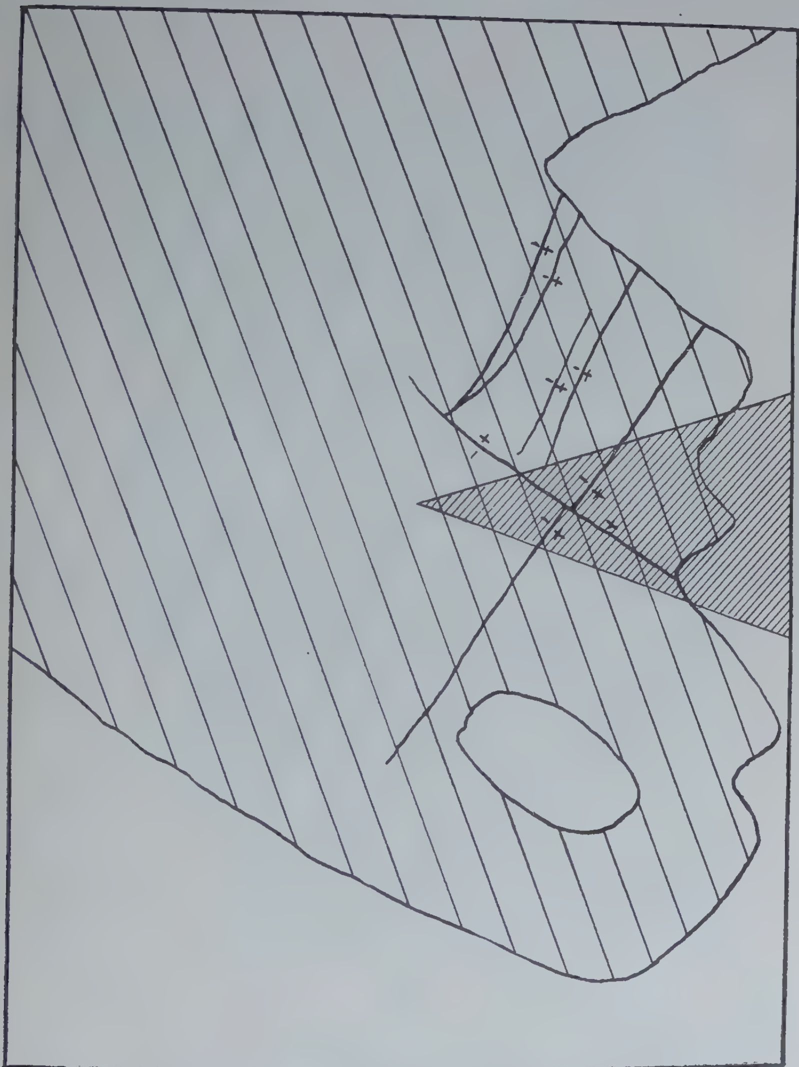


Fig. 3 Sketch map of the postglacial faults on the hillside south of the Poesten kill in Troy. The parallel oblique lines indicate the direction of the glacial striae across the exposure. The group of heavy black lines shows the position of the faults. Plus and minus signs stand for uplifted and downthrown sides respectively; the area left white is the clay-covered portion of the area mapped. The triangular shaded area is that covered by the photograph in plate 3.

The folded sandstone, as shown in the photograph on plate 3 (a view looking south 15° east from a point on the shale outcrop

west of the sandstone) exhibits overthrusting to the west, evidently a movement of ancient date for there is no observable displacement at the top of the quarry just north of the Brothers' Institution. The contortion and crushing of the sandstone is either of Posthudson or Appalachian date, presumably the former. The situation of the postglacial faults along the eastern border of the sandstone core of the overturned syncline, in the plane of the reversed dip of the stratification, is precisely where overthrust planes would be expected to arise in mountain building from a continuation of the ancient pressure. If this view be correct, it is to be expected that these thrusts would find expression elsewhere in the overturned limbs of anticlines and synclines. As the folds die out north and south, so should the faults die out north and south.

In the quarry south of the Brothers' Institution in the same sandstone core at the east end of Trenton street, there were no exposures of the glaciated surface at the time of my visit and no postglacial faults were seen.

Relation of faults to landslides in Troy. Of all the cities and towns along the banks of the Hudson gorge, Troy appears to have suffered most from the slipping of the glacial and postglacial clays. These landslides are recorded in the literature of the State. Thus on March 17th, 1859, St Peter's College lost a building in process of erection by a landslip.[1]

It is a noticeable fact that many of the older brick buildings in various parts of Troy exhibit cracked and displaced walls. A cursory examination of the city made with reference to the possible occurrence of faults in the bed rock underlying the place since the construction of houses showed a considerable number of buildings upon the terrace below the eastern wall of the Hudson river gorge in which there was a fracturing of the brickwork and a drop of the western part of the building or the relative uplift of the eastern part of the house precisely in the manner in which the rock surface south of the Poesten kill has been dislocated. The following examples taken from my notes illustrate the above statement and the exceptions to it.

A foundry in South Troy shows an uplift on the western end of the building accompanied by a displacement, traceable through three stories, which has been in part repaired. This is the most noticeable movement of the kind observed.

[1]French, J. H. Gazetteer of the State of New York. Syracuse, N. Y. 1860. p. 560, footnote.

Plate 3

View of the intersecting faults mapped in figure 3; seen from triangular point of the shaded area

A brick shop on the south side of Washington street shows a decided drop on the west end of the building. Another building on the same street shows a settling on the west end. A brownstone sill 8 inches thick is broken.

Near the river the First Ward Free School building, a three-story brick structure, on the northeast corner of River and Liberty streets, also shows a strong crack gaping upward on the south wall near the western end of the building. The western third of the southern side appears to have been uplifted in relation to the eastern part. The corner stone according to the inscription on it was laid in 1867. Directly across the street in the north wall of an electric power station, a building erected in 1886, a crack has developed near the base in the same relative position as that in the school building but nearer the ground. A straight line from the crack in the powerhouse to that in the schoolhouse has a course n. 44° e.

The brownstone Episcopal Church on the corner of First and Liberty streets exhibits cracks in the easternmost of the upper windows on the north side of the building, but these cracks are not detected from the street on the south side of the structure. The houses opposite the church edifice on the north side of Liberty street are out of plumb and overhang slightly to the south.

The nature of the ground upon which the above mentioned structures are built is not exposed in the present condition of the streets of the city. The following observations pertain to houses resting upon the rock outcrops near the base of the sloping east wall of the gorge north of the Poesten kill. Ferry street ascends this steep hillside. Some of the older houses on this street have their foundation walls laid directly upon a level cut in the slates, the contact with which may be seen just above the sidewalk. In none of these cases was I able to discover any trace of displacement in the foundation of the house or in the leveled surface of the slates. Any considerable movement amounting to as much as even a few hundredths of an inch would, I think, have been detected. The settling and fracturing of buildings in Troy shows that a movement is taking place in the materials of the low terrace upon which the lower part of the city is built. Sometimes the eastern and at other times the western end of a building appears to have settled. Where it is known that the foundations of houses are on the bed rock no displacement has

been discovered. It is true that the faults in the bed rock are limited to narrow belts and that the houses in question may lie outside of these belts. Nevertheless, both from the reversed character of the movements in the cases of the houses which have settled and from the great amount of the movement, it seems that there is no warrant for holding that the displacements in the houses are due to the movements in the bed rock. It follows from this general conclusion that the postglacial fractures in this vicinity may be and probably are older than the settlement of Troy.

It will be observed that the postglacial fractures in the bed rock, on account of having their downthrow on the western side of the fault plane, have increased the steepness of slopes inclined to the west. On the other hand, the clays of this district in themselves constitute a mass which under certain conditions of structure and access of water are competent from their sliding movement to produce all the displacements in houses observed in Troy and vicinity.

Faults in Rensselaer. In 1900, I found small postglacial faults cutting the slates on High street near 3d avenue in Rensselaer. Within the space observed there was a downthrow of 5 inches to the west, the surface being inclined also originally in that direction. Farther south where the road going to East Greenbush ascends the east bank of the Hudson gorge, a small postglacial fault was seen on a glaciated surface overlain in the cut by till. The downthrow was to the west.

At one of the localities in this vicinity, I recollect finding an instance in which a narrow strip of slate stood up between two parallel planes of faulting. This is the only case in which in eastern New York I have observed a relative downthrow to the east.

Faults in Defreestville. It was at Defreestville in the season of 1900 that my attention first became directed to the postglacial bed rock faults. A brief note of this locality is to be found in my report on the ancient water levels of the Hudson and Champlain valleys.[1] Defreestville lies opposite Albany on the east bank of the Hudson at the inner limit of the upper clay-covered terrace and nearly on the boundary line between

[1] N. Y. State Mus. Bul. 84. 1905. p. 234–36.

the Lorraine shales and the overthrust mass of Cambric strata forming the higher ground on the east of Defreestville.

The faults are to be seen in the gutter of the road which goes southeastward from the Defreestville corners and within a quarter of a mile of the corners on the east side of the road. The slates are here vertical and the faults coincide with the cleavage planes. The slates, of grayish hue, strike n. 26° e. The glacial striae of the broken slate surface run from n. 29° e. to n. 49° e. but are mainly n. 24° e.

These faults were not measured with the closeness or accuracy later employed in the study of the fractures at Troy and Copake, but are essentially as indicated in the following table and diagram [fig. 4].

TABULATION OF FAULTS AT DEFREESTVILLE

Distance from starting point on the east	Amount of throw in inches
0	.5
6 inches	1.00
12 "	4.5
8 "	.25?
24 "	4.00
18 "	1.00
24 "	.75
48 "	1.00
11.67 feet	13.00 inches

Within 11.67 feet the downthrow equals 13 inches. This rate of deformation if carried out over a belt of country 1 mile wide would produce a difference of level at one end of the line as regards the other equal to 493 feet. This fault zone, however, appears to be a narrow one. The strike of the structures at Defreestville would carry this belt to the east of the exposure in Troy. The slips are close to the great fault described by Ford, Walcott, and Ruedemann in which overthrusting is exhibited at various places where the movement has been studied. According to Dale's map [U. S. Geol. Sur. Bul. 242, pl. 1] these postglacial faults would come within the area of Lower Cambric

slates on the east of the great fault. This writer makes no mention of these recent displacements in the work referred to, published in 1904. It is to be noted that the postglacial faults at Defreestville are vertical at least at the present surface of the ground, a fact which does not preclude their belonging to the class of reverse faults due to compression.

Faults at Copake. The fractures in Copake are to be seen at the road corners ¾ mile south of the Central New England Railroad station. Altogether the exposures of the phenomena at this locality constitute the most instructive assemblage of these small fractures which the writer has seen. It is stated above that this is probably the locality originally found by Mather. The slates, lying within the area mapped as Cambro-Siluric

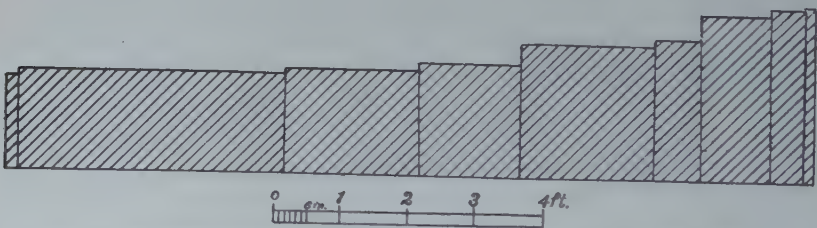


Fig. 4 A cross-section of the postglacial faults in the vertical slates at Defreestville, N. Y. The slight westward inclination of the road is neglected in the profile. The fourth fault from the right is assumed to be .25 inches throw in the table. The oblique lines in the diagram stand for shading only.

limestone on the State map of 1901, are exposed along the eastern side of the main road from Copake to Boston Corners for several yards north of the crossroads and as well on the west side of the main road in the crossroad.

The following very detailed measurements were made at this locality with the view of determining precisely the rate of displacement for a given horizontal distance, for in this way only can the throw for the belt of fracture be determined. The first measurement was made from right to left across the area north of the crossroads shown in the photograph [pl. 4]. A tape measure divided into feet, inches and quarter inches was laid over the surface of the road at right angles to the structure with the zero end of the tape on the east in each case. The surface of the rock inclined very gently to the west but no allowance has been made in the distance for this departure from horizontality.

Plate 4

Postglacial faults $\frac{3}{4}$ mile south of Copake Railroad station. Looking north by east. Photo by J. B. Woodworth

TABLE I EXPOSURE, JUST NORTH OF THE CROSSROADS, ON MAIN ROAD

Distance from 0 Feet	Inches	Westward downthrow in inches
	2.	.50
1	0.	.54
3	2.	1.70
3	7.	.04
4	0.75	.06
4	2.75	.18
4	10.	.62
5	5.75	.15
6	0.	1.00
7	2.	.62
7	9.	.09
8	7.	.80
11	10.	1.37
Total throw for 11 feet 10 inches		7.67 inches

West of the main road near the southwest corner of the crossroads within the area of the west road [*see* pl. 5] another series of faults lying to the west of those in table 1 was measured,

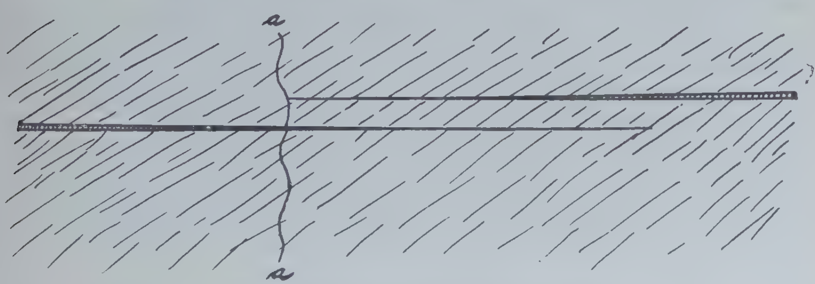


Fig. 5 Sketch of two small postglacial faults, overlapping and dying out; *a*, *a*, a ragged joint transverse to the structure

pains being taken to determine that the rocks and the fractures did not overlap into continuity with those in the first set. There is a covered space in the main road between the two sections so that précise measurements of faults which might exist in this interval were not attainable; but the zero point of table 2 is so close to the strike of the western end of the section in table 1 that few faults can intervene between the two tables.

TABLE 2 EXPOSURE, WEST OF THE CROSSROADS IN THE WEST ROAD

Distance from o Feet	Inches	Westward downthrow in inches
	6.	.24
	8.	.06
	9.25	.14
	11.	.14
1	1.	.10
1	6.	.15
1	7.5	.10
2	1.25	.12
2	5.5	.18
2	10.	.04
3	4.25	1.17
4	6.5	.02
4	9.	1.32
5	0.75	.12
5	5.	.13
6	0.2	.42
6	9.5	.30
8	6.5	.55
8	9.	.10
9	1.25	.10
9	2.5	.12
9	5.5	.10
9	7.	.08
9	10.25	.08
10	0.75	.10
10	1.	.01
10	3.	.10
10	5.25	.10
10	9.5	.38
11	1.5	.14
11	4.5	.10
11	6.5	.15

11 feet 6.5 inches downthrow equals....... 7.21 inches

For 41 feet west of the end of the above measured section the surface of the slates is exposed, showing at least seven small faults varying from half an inch to 1 inch downthrow to the west. There are also numberless smaller faults as in table 2;

Plate 5

Postglacial faults $\frac{3}{4}$ mile south of Copake railroad station; west of main road; looking south. Photo by J. B. Woodworth

but the roadway has been much worn and weathered and precise measurements are unattainable and were not attempted.

The two tables show a closely similar rate of dislocation for a given distance within the belt. Thus in the first case there is a displacement of 7.67 inches in a distance of 11 feet, 10 inches, and in the second case a displacement of 7.21 inches in a distance of 11 feet, 6 inches, an average of 7.44 inches in a distance of 11 feet, 8 inches, nearly 1.9 inches a yard, or 336.7 feet a mile.

The apparent uplift on the east at this locality, basing the estimate upon the two measured portions of the sections and upon that which was estimated only amounts to nearly 2 feet within little more than the width of the highway. If allowance is made for the very minute fractures revealed by a close examination of the glaciated surface with a pocket lens, it seems a conservative estimate to state that the dislocation at this locality exceeds 2 feet of vertical displacement.

The faults at this locality lie with rare exceptions in the cleavage planes whose strike is n. 30° e. and whose dip is 60° e. The glacial striae run n. 10° w.

At a point on the roadside where the slates have been cut away in grading the road, chance was given to observe the appearance of the cleavage faces for a foot or more below the surface along the plane of a fault. Although the vertical movement on this plane was less than an inch, well formed vertical slickensides were found. The surface of the slickensides was dull and water stained without that polishing which is characteristic of faults along which movement has recently taken place.

Near the northern end of the exposure on the east side of the road two small parallel faults were seen overlapping [*see* fig. 5], one dying out southward, the other northward, as in the accompanying figure. At another point at this locality a fracture cuts the slaty cleavage obliquely, but the downthrow is here, as elsewhere in this vicinity, on the west.

Fractures near Pumpkin Hollow. Three fourths of a mile northwest of Pumpkin Hollow, at a point about a mile west of Copake Lake in the town of Taghkanic, postglacial fractures occur in slates on the western slope of a hill. The glaciated surface was at the time of my visit exposed in small areas of outcrop. Within a distance of 200 feet up the slope I made a rough measurement of 17 inches of displacement by small faults, varying in individual cases from a quarter of an inch up to nearly 3

inches of throw. The larger faults are from 1 to 3 feet apart. The downthrow in each case is to the west. The slates, in some outcrops phyllitic, dip east at an angle of about 60°, and strike n. e. and s. w.

The tectonic structure of the rocks in this vicinity is not ascertainable from local observations. At the base of the hill on the west of the public road there is a large nest of white vein quartz in the slates which may or may not have been a factor in resisting and localizing the effects of the thrust which produced the faults.

South of this locality in the road corners at Pumpkin Hollow, a postglacial fault with a throw of .75 inch was observed in blue, crumpled slates.

Two and a half miles southeast of Taghkanic village along the road to Chrysler pond, on the hillside south of the road and near the eastern end of a swamp in the east-west depression which exists there, one postglacial break of about an inch with a downthrow on the west was found in a rather resistant rock shot through with quartz veins.

When one considers the smallness of the exposures which are available for observations—most of the rock remaining covered with drift or soil and many of the exposures being deeply weathered—it must be admitted that the slate belt through Copake and Taghkanic is extensively broken by small postglacial faults. Owing to the eastward dip of the slates, exposures are naturally more abundantly observed on the western than on the eastern slopes of the hills throughout this region. The failure to find these fractures on the eastern slopes, where indeed many exposures also occur, is perhaps explained by the fact that the little steps produced by the faults serve to catch and hold the soil from slipping and thus to prevent exposures.

The rocks of this belt are mapped as "Metamorphosed Hudson" on the geologic map of New York published in 1901.

General remarks on Hudson river area

In the season of 1904 a reconnaissance was made of the district from Glens Falls southward on both sides of the Hudson river. All the certain and measurable faults of this character so far found have been described in the above account. It will be observed that the phenomena are apparently restricted to the east side of the river along the western base of the Taconic-

Green mountain belt in a region of folded, faulted, and overthrust slates ranging in age from the Lower Cambric to the summit of the Lower Siluric. Many outcrops were found in which postglacial faulting is to be suspected, as in the case of the soft black slates in Argyle, but the weathering away of the original glaciated surface has removed the evidence upon which the proof of the movement depends. Over a large part of the rounded slate hills of Argyle, the glacial drift has been entirely removed, evidently by currents of water marginal to the receding ice sheet, so that weathering has had a deep effect upon these fragile slates.

A peculiar distribution of outcrops of slate on certain hillsides along the southern border of the Fort Ann quadrangle is in accordance with the local *en echelon* distribution of many faults, but this rhythmic succession of small cliffs in groups on the hillsides may be due to the manner of the glacial erosion, the uplifted side or top of the small cliffs having the appearance of an imperfect *roche moutonnée* the lower side of which has been plucked away. These cliffs form an advancing and receding, ascending and descending, series of exposures, the distribution of which is analogous to that of the small cliffs produced by the spacing of such faults as are shown in figure 5 of this paper. This class of outcrop forms deserves further investigation from several points of view and they can not be said at present to be the result of faulting.

From Fort Edward down the Hudson river as far as Troy no postglacial faults of an undoubted character were found. In the rock cut for the electric railway near the mouth of the Moses kill between Fort Edward and Schuylerville, the slates exhibit bright and shining slickensides near the present surface of the ground attesting to slight movements along gliding planes within the zone to which weathering has ordinarily penetrated and blemished polished surfaces that have not been kept bright by secular or spasmodic recent motion.

Judging from such occurrences as have so far come to light in eastern New York, these postglacial faults occur sporadically, dying out north and south along the strike of the Cambric and Lower Siluric slate belt. From the observed relations to the axes of folds at Troy, the movement in the slates appears to be clearly one of overthrust in a region of already overturned and faulted anticlines and synclines, an overthrust acting in the same

direction as the ancient mountain-building pressures which produced the eastward dipping cleavage. If the case at Troy be taken as a clew, the faults might be expected, as pointed out above, to occur most abundantly and most pronouncedly on the overturned flanks of the synclinal axes in the zone of strain in which an overthrust normally begins in folded strata.

From the data so far at hand it can not be assumed that the measured rates of dislocation within any given horizontal distance of exposure continue beneath the drift-covered portions of the field, and consequently the attempt to determine the relative uplift of the surface at the base of the mountains, as compared with the level at the shore of the Hudson, must give an uncertain, probably minimum, measure which will vary also in amount from north to south along the extension of the phenomenon. Even this possible difference of level between the eastern and western limits of the faulted zone may be only apparent, the faulting being effected by a rotational movement of the slices of rock between the fault planes. A steepening of the high eastward dip of the cleavage would produce the observed local result without changing the attitude of the surface as a whole.

The exposures in eastern New York are so near tide level and bench marks accurately determined that it would appear desirable to make precise determinations of the level of certain points along the eastern and western limits of the zone of faulting with the view of comparing the measurements with a second series of observations made after some lapse of time for the purpose of ascertaining the nature of the movement if it is still in progress. For the same reason observations might be made at particularly favorable sites where the faults are well exposed through some such means as the perhaps too delicate bifilar pendulum affords so as to obtain within a few days an indication of the tilting if it is going on at the present time.

There are no observations as to the depth to which the faults affect the slates. I am not aware that the faulted belt is one peculiarly liable to earthquake shocks at the present time.

In conclusion, it may be stated that the postglacial faults appear to lie in a zone of overthrusting extending along the western base of the Taconic and Green mountain uplift of folded structures from near the Highlands of the Hudson into the province of Quebec, with at present notable gaps in the obser-

vations. A like zone of displacement parallel in direction but far to the east is found in southeastern New Brunswick. While the observed small fault scarps are postglacial in origin, it can not be said that the faulting is wholly of postglacial date; secular preglacial and interglacial faulting along the same zones would have had the evidence effaced by glacial erosion. Observations have not so far determined whether the movement is in progress or not.

When we compare these structures on the east of the Hudson in the vicinity of Troy with the faulted structures on the west in the vicinity of Little Falls on the southern border of the Adirondacks, the upper Hudson valley assumes the appearance of a broad graben, bounded by normal faults on the west and overthrusts on the east, an unsymmetrical structure in which the rock movements of unlike character are probably also of dissimilar age.

Evidence of dislocation in northern New York and Quebec

Evidence of faulting which appears to be of recent date, though not definitely determined to be postglacial as in the case of the interrupted glaciated surfaces, was observed by the writer at a number of points on the north, of which the two most striking instances were seen on Trembleau mountain, at Port Kent, N. Y., and on Mt St John (or Monnoir) near St Gregoire in the province of Quebec.

Probable fault on Trembleau mountain. Trembleau mountain is a mass of norite projecting into Lake Champlain at Port Kent. The eastern slope of this mass is benched more or less definitely at an elevation of about 100 feet above the lake. Approaching the foot of the hill from the pasture southwest of the railroad station at Port Kent, on the level of the old delta of the Ausable river, the rocky bluff is most easily ascended at a point where the rock is broken down and a shallow gully encumbered with blocks of local derivation leads up to the platform mentioned. This depression is traceable southward over the top of the bench along the line where otherwise its surface would join the steeper slope of the mass in its rear. The rocks are massive, and faulting is consequently difficult to prove; but the slopes are interrupted with an apparent uplift of the bench on the east, and the zone of displacement, a few feet wide, forms a trench in which large angular blocks have come to rest. This

part of the slope of the mountain was wave washed during the late marine invasion of the Champlain valley. I could not determine that the delta surface immediately north of this locality exhibited a trace of dislocation attributable to the postglacial origin and continuation of this supposed fault into the rocks underlying the delta.

Probable fault on Mt St John, Quebec. Mt St John is the small conical elevation of basic igneous rock seen standing up on the plains between northern Vermont and the St Lawrence river. Viewed from the train on the Intercolonial Railway between Chambly and Beloeil, St John presents an outline on its northern aspect like that shown in the appended sketch, figure 6. On ascending the mountain as high as the quarries

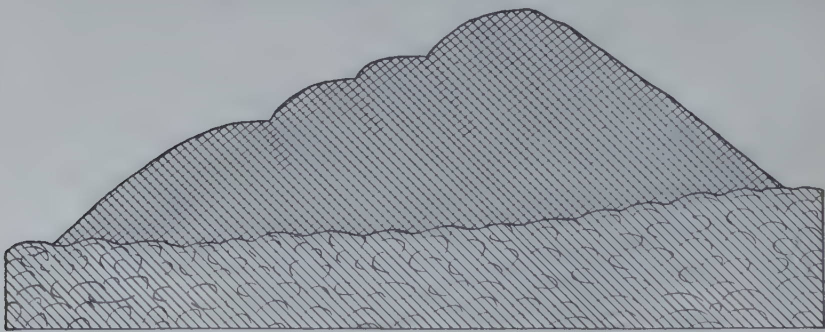


Fig. 6 Outline of Mt St John (Monnoir) viewed from the north. The lower part of the sketch is meant to show the top of the forest.

worked on its eastern face near the summit, it is found that the steps shown in the above view are separated from the slope back of them by evidences of fracture, and in one case, I believe, also of dislocation. The most pronounced fissure which I examined at the level of the highest quarry showed a gap partly filled with large blocks which had tumbled in from the sides and the slope of the mountain above the bench. The fissure opens at the surface much above the level to which, according to my determinations, the sea extended in the postglacial marine invasion; moreover, the chasm is not of the wave-made type. When the sea makes a chasm it removes in so doing the blocks of rock in and about it or above the level of the chasm floor. The annexed sketch, which below the surface line is partly conjectural, gives at least the superficial aspects of the locality as I saw them.

Postglacial faults in New England

Two instances at least of these movements are now known.

Postglacial faults at Attleboro, Mass. Postglacial faults of the class described in this paper are now known to exist in southern Massachusetts. In April 1905 I found them well developed in vertical Carboniferous sandstones and shales without slaty cleavage on the south side of the axis of the Attleboro syncline at a locality a little over a mile southwest of Attleboro, Mass. The outcrops are near the point where the Thatcher road bridge spans the railroad from Boston to Providence. The principal ledge is illustrated in a report on the geology of the

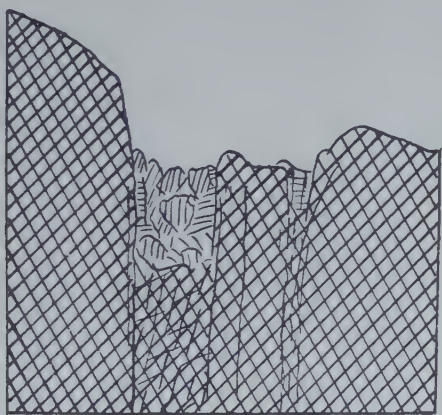


Fig. 7 Diagrammatic cross-section of supposed fissure near the top of Mt St John, looking west by north

Narragansett basin,[1] but these faults were not particularly noted at the time the field work was done. At the outcrop near the railroad track I measured a downthrow to the south of 3 inches distributed over five small faults. The largest throw measured was 1.07 inches and the smallest measured was .24 inches. These were widely distributed over a space nearly 100 feet wide measured across the strike of the beds. The faults occur in the plane of the bedding. The strike of the beds at this locality is n. 52° e. The rock surfaces are usually well glaciated and the detection of postglacial slips is accordingly readily made. In an outcrop in the field near by there is an apparent downthrow of 1 foot to the north but weathering has somewhat obscured the evidence.

[1] *See* U. S. Geol. Sur. Monograph 33. 1899. pl. 7, p. 175–76.

In the old quarry on Ides hill ancient faults are well marked by slickensides in the bedding planes showing that this movement is by no means a recent one.

Postglacial faults in New Hampshire. Prof. C. H. Hitchcock reports a case of postglacial faults in slates on the summit of Kilburn's Crag, near Littleton, N. H.[1] He states that "segments of the slate have been crowded up (or down) a quarter of an inch since the glaciation was effected. When made the smoothing must have been continuous; now one part of the ledge, with the striae upon it, is a quarter of an inch higher than what is adjacent, and the change is abrupt. These jogs in the ledge are small faults made by the same crowding from one side that has lifted up the mountains." He supposes such cracks to have been accompanied by earthquake shocks, intimating that the total movement took place at one time.

In a letter to the writer dated June 19, 1905, Professor Hitchcock states that as he recalls the faults at Kilburn Crag their course is nearly east and west and the downthrow on the south side.

General conclusion

The detailed observations given in this paper, slight and incomplete as they are, show that the change of level or the so called tilting of the land in and about the New England district since the retreat of the Wisconsin ice sheet has been accompanied by the fracturing of rocks in certain zones of structure presumably so disposed as to yield to stress by small repetitive faults mainly with a downthrow to the northwest in structures whose strike is northeast and southwest, and with a downthrow mainly to the south in structures whose strike is nearly east and west. While the throws as pointed out appear from the reports to be on the whole greater along the northern borders of New England in the field described by Matthew and Chalmers than on the south in New York and while at the same time the examples from the interior of New England so far reported also favor the view of uplift on the north and downthrow on the south, the examples so far known are too few to warrant drawing the conclusion from them that the degree of faulting is commensurate with the extent of the tilting and change of level. Wherever we have full evidence of the nature of the faults they appear to

[1] "The Geology of Littleton, New Hampshire," reprinted from *History of Littleton*, 1905, p. 28–29.

be of the reverse type, indicating compression. The direction of the throw must depend upon the attitude of the planes of structure—stratification or cleavage, or both—along which the movement takes place. In stratified rocks which have been thrown into anticlines and synclines, and have been subsequently rather deeply base-leveled, it is probable that the continuance of the lateral pressure which gave rise to the folds would concentrate the horizontal strain upon the cores of the synclines in such a manner as to cause successive boat-shaped layers of rock with their wedge-shaped cross-sections to rise upward. By reason of the inward dip of the strata about the synclinal axes the appearance of overthrust would appear in the slips which marked the movement, as shown in the accompanying theoretical diagram [fig. 8]. Thus synclinal cores must have a tend-

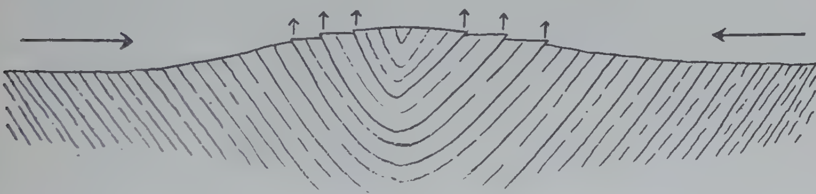


Fig. 8 Diagram showing cross-section of a normal upright syncline with a rising core due to slipping of successive layers in the trough under lateral compression

ency independently of resistant remnant beds in their troughs to stand above the general level or to give rise to upfolds in the horizontal newer strata which in certain districts lie unconformably upon them. Small faults of this nature may arise in folded strata without direct connection with those greater and more deep seated faults which appear so abundantly in eastern North America to have had their origin in the fracture and displacement of the crystalline Precambric terrane. It is worthy of note that the few instances of postglacial faults as yet reported appear to be everywhere associated with highly inclined strata. It is to be presumed that the same stresses are equally operative in the regions of horizontal strata with consequent displacements which take the form of horizontal thrust-planes whose time of movement is not so readily determined.

The bearing of these observations and inferences upon the ancient water levels of the Hudson valley in the present state of our knowledge would seem to indicate that the shore lines of the eastern side of the Hudson gorge north of the Highlands

are somewhat higher than the equivalent shore lines of the western side. It is not clear however that the amount of this difference is definable. In the vicinity of Troy it is greater than 1 foot—how much greater can not at present be stated. If the shore lines on the sides of the Hudson valley in that latitude were features whose elevation could be exactly measured, a precise leveling would undoubtedly afford a fairly accurate measure of the deformation on an east and west line due to this cause since the formation of the ancient marks of the highest stand of the water.

It is to be hoped that the numerous examples of these postglacial movements which undoubtedly are to be found in the numerous exposures of the bed rock in and about New England will shortly furnish data for a concise statement of the extent to which the warping of the crust has taken place in this manner and that further studies will afford evidence concerning the nature of the movements as to whether they are secular or spasmodic.

STRATIGRAPHIC RELATIONS OF THE ONEIDA CONGLOMERATE

BY

C. A. HARTNAGEL

The Oneida conglomerate is a formation which has long been known in New York geology. Occupying as it does, in sections where it is best known, a position directly above the Lorraine shale, and being composed of coarse pebbles, it has always been easy to recognize.

This conglomerate was early described by Emmons[1] under the name of "millstone grit," and the stratigraphic position assigned to it by him was above the "graywacke," or "metalliferous graywacke," and below the "saliferous rock." The former corresponds to the Lorraine shale and the latter to what is currently known as the Medina, though the "saliferous rock" was in many cases, as an examination of his text shows, confused with the Vernon red shales of the Salina, and in Herkimer county with the Clinton, since in the latter locality the gray band of the Medina is correlated with the upper Clinton sandstone.[2]

Outcrops of the conglomerate were noted by Emmons from Steele's creek near Ilion and westward at several localities to the south of Utica, and from here west as far as 3 miles south of Rome. Another locality [p. 35] mentioned by Emmons is at the lower Genesee falls at Rochester. This statement, however, is clearly an error, as this locality is again mentioned for the "gray band" which Emmons placed above the Medina or "saliferous rock." That Emmons did not intend to include the "millstone grit" in the rock series at the above locality is shown by his statement on page 96 where he says, "There (Rochester) the red saliferous rock being the lowest in view, this (the millstone grit) is undoubtedly concealed below it." The result of the observations of Emmons as shown by his text and the plate accompanying was that the Oneida conglomerate occupied a position below the red Medina and that the conglomerate extended as a concealed formation westward beyond the limits of the State.

---

1 Geological and Agricultural Survey of the District adjoining Erie Canal. 1824. p. 35, 95–102

2 *See* Vanuxem. Assembly Doc. 1838. No. 200. p. 268.

The first geologist assigned to the third geological district of the State was T. A. Conrad. The district included the area of the Oneida conglomerate. Conrad describes the members of the Siluric under the general heading, "Sandstone series or second division." The lowest member described is the "gray sandstone and shales of Salmon river"[1] (=Oswego sandstone). Under this chapter Conrad states [p. 168]: "Near Clinton, in Oneida county, there is a silicious conglomerate, dipping at an angle of 10° to s. w., which is either a portion of this formation or of the next above it, but time has not yet been given to the investigation of its true relative position." Above the shales of the Salmon river, Conrad places the red or variegated sandstone of the Niagara river. The latter is the "saliferous rock" of Eaton as described from western New York, to which the term Medina is now applied. Under the "Mineral character," etc., of the red sandstone, Conrad states [p. 172]: "At the falls of Oswego the red sandstone is abundant, of a coarse texture, and does not appear to be much used at present. Lines of cleavage oblique to the plane of stratification, are here very obvious. The upper layers consist of a coarse conglomerate or pudding stone. The sandstone near the top of the series alternates with red shale, both containing Fucoides alleghaniensis, the shale seeming to be a mass of them cemented by argillaceous and ferruginous earths." [p. 173]

The work of Conrad as geologist of the third district terminated with his appointment as first State Paleontologist and Vanuxem was assigned to his place as geologist of the new third district.

In the annual report for 1838 the Oneida conglomerate is described by Vanuxem as follows [p. 267]:

Millstone grit of Professor Eaton.—Immediately on the green shale [Lorraine], without any connection other than support, reposes this quartz conglomerate, a rock of some interest, being the first one met with made up of rolled stones or pebbles. They are of vitreous quartz. This rock extends throughout Herkimer and Oneida, with a thickness of 30 or more feet. . . The lower part of the conglomerate is almost invariably highly charged with sulphuret of iron or pyrites, the part containing it usually from 5 to 6 inches in thickness. . . Resting on the millstone grit, a series of shales and sandstones are discovered, extremely diversified in composition, color, thickness, contents or associates, meriting the name protean mass [=Clinton]. This is the saliferous rock of Professor Eaton, including the gray band. . . [p. 273] The northern edge of the millstone grit

[1]Geol. N. Y. 3d Dist. Assembly Doc. 1837. Ed. 2. No. 161, p. 159, 166.

Plate 1

Contact between the Frankfort (Lorraine) shale and the Oneida conglomerate. Moyer creek, 3 miles southwest from Frankfort, Herkim

corresponds very nearly with a line extending through the villages of New Hartford and Vernon Center. It shows itself in the water courses to the east of Utica, near New Hartford in many places, south of Hampton village, also at Oneida Springs, and the stone pound near Stony creek to the north and west of Verona. . . It presents likewise a few of the large imperfect fucoides, and no other fossil. . . In a practical point of view this rock in Oneida county forms an important line of division in the description of the rocks which occur to the north and the south of it, dipping as the rocks do to the south and west. . . [p. 282] In no part of Oswego (county) were we able to discover the millstone grit as a solid rock or mass. We had reason to believe that it had existed near Cleveland [on Oneida lake], from the prodigious number of large fragments or blocks which are found to the east of the village, on the high bank and in the bank and on the shore of the lake, as well, likewise, about a half mile from that place to the east, on the road to Rome.

In the summary of this report, Vanuxem states [p. 284]:

"Millstone grit"—All the preceding rocks are below this mass, all passing under it. This rock is the first mass of pebbles met with in the series. The pebbles are of glassy quartz, same as those met with in the Calciferous, only more waterworn. Nothing extraneous in this rock, but pyrites and a few large imperfect fucoides.

North of Wood creek and Oneida lake, the green [=Oswego] and red sandstone [=Medina] follow the last described series [=Lorraine], but south of the Mohawk, the grit follows that series [=Lorraine] and upon the grit reposes the protean [=Clinton] group. The gray and red sandstone, within the limits examined, presenting no well defined common character of union with the protean group, requires more extended observation west, to remove the ambiguity occasioned by the absence of the grit in Oswego [county].

In the report as above given, Vanuxem extended his observations farther west than his predecessors and examined the Oneida at its type section. It is clear, however, from the above, that he regarded the Oneida as above the red Medina shales which follow the Oswego sandstone.

In the annual report for 1839, page 242, Vanuxem states what he considers to be the proper correlation westward of the Oneida, as follows:

The "millstone grit," which is 30 and more feet in thickness in Herkimer and Oneida, gradually attenuates in going westward, being from 4 to 5 feet at Rochester. The materials of which this rock is formed, gravel and sand, prove that their source was easterly. In Herkimer and in the eastern part of Oneida, the pebbles are larger and the mass thicker, the sand increasing going west, whilst the pebbles diminish in the same direction. Thus, in Cayuga the pebbles are rare, and I know

not that they have been noticed in the "gray band" at Rochester, the continuation or equivalent of the "millstone grit."

In the report for 1840, page 373, the succession of rocks as given by Vanuxem is as follows:

1 Protean group.
2 Oneida conglomerate.
3 Medina sandstone.
4 Salmon river sandstone. (=Oswego sandstone).
5 Pulaski shales } (=Lorraine).
6 Frankfort slate }

In the above report, the term Oneida conglomerate is used for the first time and as defined it is the equivalent of the "millstone grit" of Professor Eaton. This is also the last of the annual reports in which Vanuxem considers the conglomerate. A detailed account is given in the final report comprising the geology of the third district, to which reference will be made later.

While Vanuxem was carrying on his investigation in the third district, Hall was carrying on similar work in the fourth district, comprising the western portion of the State.

In the annual report of the fourth district for 1838, page 294, Hall states, in referring to the Medina sandstone: "The upper stratum of this rock has been called 'grayband,' by Professor Eaton; it, however, appears to be only a gray stratum of the sandstone, generally more silicious and indestructible than the rock below."

In the same report, in describing the Medina in the town of Wolcott, he states [p. 325]: "The upper layers are hard, silicious and occasionally pass into a conglomerate or pudding stone."

With the publication of the final report on the geology of the third district in 1842, Vanuxem concluded his investigations as a member of the State survey. In this volume, under the descriptions of the formations and in the geology of the counties in which the Oneida was known, is contained an extensive account of the Oneida conglomerate. The succession in descending order as given by Vanuxem in his final report follows:

Ontario division {
1 Niagara group.
2 Clinton group.
3 Oneida conglomerate.
4 Medina sandstone.
5 Gray sandstone of Oswego.
}
6 Hudson River group.

As synonyms for the Oneida conglomerate, Vanuxem gives the following: "Shawangunk conglomerate," "millstone grit

Plate 2

Cross-bedding in Upper Medina sandstone. South branch of Moyer creek, 200 yards above and about 110 feet higher than the conglomerate shown in plate 1. This horizon is approximately that of the "gray band" of the Medina as known in western New York

of Eaton," "gray band of Rochester"; being a sandstone to the west, and a conglomerate and sandstone to the east.

In the final report of the district geologists, Vanuxem alone defined the Ontaric system as above stated. Hall and Emmons included the Oneida conglomerate as the highest member of the Champlainic system and the Medina sandstone as the lowest member of the Ontaric or Upper Siluric. Mather, however, was more in harmony with Vanuxem and the Shawangunk conglomerate [p. 2] alone was included in the Ontaric system. However, the other members present above the conglomerate were referred to by Mather as the [p. 353] "pyritous strata and red shales and grit." In his report [p. 2] this conglomerate is designated the "Oneida or Shawangunk conglomerate."

In a "Review of the New York Geological Reports," contained in the *American Journal of Science* [Ser. 1. 1844. 47:354], the writer of the article follows Emmons and Hall and includes the Oswego sandstone and Oneida conglomerate in the Champlainic division and the Medina sandstone is made the base of the Ontaric.

In publications following the final reports of the district geologists, the Oneida gradually came to be regarded as belonging to the Ontaric, to which place it had been assigned by Vanuxem. Among the reasons advanced for regarding the Oneida as Ontaric was the presence of Fucoids, either identical or closely allied with Arthrophycus alleghaniensis, a fossil very common in the upper portion of the Medina sandstone.[1]

On the other hand, the stratigraphic position of the Oneida given by Vanuxem as above the Medina has, in the past, not been retained. In nearly all publications from Vanuxem's report to the present time, the Oneida when considered as a distinct formation has a position below the Medina. In this connection it is interesting to note that in a letter to one of the editors of the *American Journal of Science* [Ser. 2. 1864. 38:121], Col. E. Jewett, "states that he has found Arthrophycus harlani, a characteristic Medina fossil, in the Oneida conglomerate, near Utica, Oneida co., N. Y., and also as he observes, for stratigraphical reasons, that the Oneida conglomerate is in fact only a northern portion of the Medina sandstone. The occurrence of this or a related fucoid is stated by Dana in his *Manual of Geology* [1863, p. 230], a specimen having been obtained from the rock near Utica by the author more than 30 years since, which was in all probability of the same species, although, as

[1]Dana, J. D. Manual of Geology. 1863. p. 231.

the specimen was afterward lost, the fact is given in the Manual with a query as to the species."

It is a noteworthy fact that in reviewing the works which have been published relating to the Oneida conglomerate and specially those which consider the Oneida as below the Medina, one can scarcely find anywhere a reference which attempts to show or even infer that Vanuxem's conclusion was not a correct one. It is also not an easy task to show specifically how the Oneida came finally to be regarded by geologists as lying below the Medina.

It should be mentioned, however, that the Shawangunk grit was regarded by all the early geologists as the stratigraphic equivalent of the Oneida conglomerate—a correlation which no longer holds good, the two terms being used as synonyms. Since we have red shales lying above the Shawangunk conglomerate, the same condition may have been assumed for central New York and thus the order of the beds determined.

Again the overlapping of the upper part of the members of the Ontaric system in central New York was formerly regarded as a thinned portion of the whole formation and not of the upper part alone as is now known to be the case.

The critical section for the stratigraphic position of the Oneida conglomerate is along the Oswego river. At the mouth of the river and along the shore of Lake Ontario we find the typical gray Oswego sandstone. Above the city and along the river banks, one can see that above the Oswego sandstone we have the red sandstones and shales of the Medina. These rocks show at intervals, and are specially well shown 12 miles farther south at the city of Fulton, at which place we have the falls of the Oswego about 10 feet in hight. The fall is due to the resistant character of the rocks and an examination shows that the rock is a quite coarse conglomerate, in which the fossil Arthrophycus alleghaniensis is found in great abundance and in a fine state of preservation. The rock above the fall can not be observed but enough is known to show that the conglomerate is not far below the Clinton formation.

In New York, the fossil Arthrophycus alleghaniensis Harlan is found in the Oneida conglomerate near Utica, at its type section in Oneida county, at the falls of the Oswego, and in the upper Medina west to the Niagara river. It is also found in Canada. Throughout this section this fossil is practically limited to the upper portion of the Medina and is thus important as an horizon marker. The presence of this

fossil and the stratigraphic relations of the Oneida conglomerate as shown in the Mohawk valley can leave no doubt of the upper Medina age of the Oneida conglomerate.

The presence of the fossil Arthrophycus alleghaniensis Harlan in Pennsylvania, Maryland and Virginia is of special interest. Vanuxem[1] in referring to Pennsylvania says:

> There this fossil appears in the same position, and in sandstone of like diversity of character as to color, etc., as in New York generally. It is abundant on the Juniata, and on the west branch of the Susquehanna. I found this remarkable fossil in Virginia, about 15 years ago, near the top of the Flat-top mountain, a little to the west of the Salt valley above Abingdon. It was in white sandstone, which caps that mountain, and which rests upon a red sandstone reposing upon a gray or olive calcareous sandstone containing numerous testaceous fossils, referable rather to those of the sandstone shale of Pulaski [=Lorraine], than to any other part of the New York system.

The later work by Stevenson[2] also shows that this fossil is found in the upper Medina of Pennsylvania.

In Maryland[3] the lower portion of the Medina is known as the Juniata formation and the upper portion as the Tuscarora formation. No fossils are mentioned as coming from the former and Arthrophycus is the only one mentioned as occurring in the latter.

The Tuscarora is regarded as, "perhaps nearly identical with the White Medina of the Pennsylvania and New York surveys."

In Wills Creek gorge in Maryland, Professor Schuchert[4] has constructed the following descending section for the Medina.

1 Tuscarora. Snow-white to light gray quartzite, in places a fine conglomerate; Arthrophycus harlani the only fossil—287 feet.
2 Juniata. Interbedded dull red sandstones and shales. In Wills Creek gorge 530 feet can be seen, but the total thickness, on the basis of that in Bedford county, Pennsylvania, is probably not less than 730 feet.
3 "Hudson River shales."

From the above it will be seen that the fossil Arthrophycus alleghaniensis Harlan. wherever known, is most characteristic of the upper Medina and appears to be practically confined to this horizon and that from both stratigraphic and paleontologic reasons, the Oneida conglomerate is to be considered as a part of the upper Medina.

---

[1]Geol. N. Y. 3d Dist. 1842. p. 71.
[2]2d Geol. Sur. Pa. Rep't of Progress. T2. 1882. p. 91.
[3]Md. Geol. Sur. Allegany Co. 1900. p. 86.
[4]U. S. Nat. Mus. Proc. 1903. 26: 424

In another work, the writer[1] has described the Medina of New York under two divisions, namely the lower and the upper, which may be regarded as corresponding to the Juniata and Tuscarora of Pennsylvania and Maryland. The passage from the lower to the upper is marked by a change in character of sedimentation and in the color of the rock. At the Niagara river, the lower red shales are followed by about 25 feet of gray quartzose sandstone. This bed of sandstone corresponds approximately to the base of the Oneida or upper Medina from Oneida county eastward, both occurring at a little more than 100 feet below the base of the Clinton. This gray sandstone marks the introduction of marine life into the Medina. At Niagara the gray quartzose sandstone is followed by a series of thin shales and sandstones and is terminated above by the "gray band" which is the upper limit of the Medina.

It was pointed out in a previous paper[2] that the Shawangunk conglomerate of eastern New York, probably represented an age later than the Oneida, with which it had been generally correlated. Though at that time the Oneida conglomerate was regarded as of the same age as the Oswego sandstone, the present study shows still more clearly that the Shawangunk conglomerate should not be regarded as basal Medina, but as Salina.[3]

In a recent publication,[4] Dr. A. W. Grabau has regarded the Oneida as a basal conglomerate, which, in age, ranges from the lower (=Oswego sandstone) Medina to the upper Medina. In this connection it should be noted that at the type locality for the Oneida, which is near Verona in Oneida county, the conglomerate is just below the Clinton and that this relation to the Clinton holds for 40 miles eastward to beyond Vanhornsville in Herkimer county, where is shown the last known exposure of the Oneida to the east, and thus this formation throughout this extent must be of upper Medina age.

This fact, together with the Oswego river section, tends to show that the Oneida wherever known holds a position which is never far below the base of the Clinton. Hall[5] records the finding of a conglomerate or pudding stone at the top of the Medina at Wolcott in Wayne county. A similar reference is also made to this locality in one of Hall's district reports.[6] As the top of

[1] N. Y. State Mus. Bul. in press.
[2] N. Y. State Pal. An. Rep't. 1903. p. 346.
[3] The reasons for considering the Shawangunk conglomerate as of the age assigned above, are stated in a paper on "The Siluric and Lower Devonic Formations of the Skunnemunk Mountain Region" in this bulletin.
[4] N. Y. State Mus. Bul. 92. 1906 p. 123.
[5] Geol. N. Y 4th Dist. 1843. p. 42.
[6] An. Rep't 4th Dist. 1838. p. 325.

the Medina is but a few feet above the lake at Wolcott, this locality probably represents the most westward extension of what may be regarded as the Oneida conglomerate.

Champlainic and the Ontaric or Upper Siluric contact

In all the recent publications on geology, the Oneida conglomerate when considered apart from the Medina is made the base of the Ontaric division. The Oswego sandstone which has been considered the westward extension of the Oneida has also been generally regarded as belonging to the Ontaric. From the considerations which have been stated, it follows that if we regard the Oneida as the base of the Ontaric, the lower red Medina and the Oswego sandstone must be considered as belonging to the Champlainic, or else the base of the Ontaric must be placed lower than the Oneida conglomerate.

It is not the purpose of the writer to here state just where the line between the Champlainic and Ontaric divisions should be drawn, but rather to state some of the factors which must be considered in the final solution of the problem.

In comparing the results of the early geologists, it should be remembered that Hall and Emmons included the Oneida conglomerate as the highest member of the Champlainic system and the Medina sandstone as the base of the Ontaric. Vanuxem on the other hand regarded the Oneida as above the Medina and made the gray Oswego sandstone, which is below the red Medina, the base of the Ontaric.

The later works of Hall show that he finally included the Oneida as the base of the Ontaric, but always held that the Oneida was below the Medina.

From Oneida county eastward, the Oneida conglomerate rests on the Champlainic strata and represents the base of the Ontaric as at present defined, only in the sense that it is the lowest Ontaric formation present. In a like manner the higher Ontaric formations rest on the Champlainic strata, the farther east we go, and at Becraft mountain, the Manlius, the highest member of the Ontaric, rests on unconformable Champlainic strata.

The passage of the Lorraine into the Oswego sandstone can be observed in Oswego county and has been described by Vanuxem.[1] It is then evident that we have no unconformity between the Lorraine and the members of the Medina formation in Oswego county.

Of the condition in Pennsylvania, Stevenson[2] states, "the

[1]Geol. N. Y. 3d Dist. 1843. p. 67.
[2]Geol. of Bedford and Fulton Counties. 1882. p. 92.

passage from the Lower Medina to Hudson is imperceptible, and the red or brownish red shales yield Ambonychia radiata and Rhynchonella capax."

Stevenson regarded the Oneida as below the Medina, but mentions the fact that the Oneida at this locality is absent and that the conditions as above stated prevail.

In Ohio and Indiana, the Richmond beds follow the Lorraine. The Richmond beds are fossiliferous and their fauna contains a number of Trenton forms. If we regard the Oswego sandstone as following directly the Lorraine in New York State, then the Richmond must, in part at least, be the time equivalent of the Oswego sandstone.[1]

At present the Oswego sandstone is regarded as Ontaric and the Richmond beds as Champlainic.

It is generally held that the Champlainic period was brought to a close by the Taconic revolution. In eastern New York the entire portion became land, but deposition continued in the vicinity of Oswego county, since the Oswego sandstone follows the Lorraine without break.

If we consider the Champlainic as being brought to a close with the beginning of the Taconic revolution, then the Oswego sandstone could be made, as it is at present, the base of the Ontaric.[2] The Oswego sandstone is practically without fossils, so from a basis of paleontology alone it can not be correlated with the Richmond beds. It seems, however, that the Oswego sandstone represents a near shore condition which was unfavorable for the existence of life but farther west the Richmond fauna flourished under more suitable conditions. The very marked paleontologic break at the close of the Lorraine is another factor in favor of making the Ontaric begin at the base of the Oswego sandstone.

The absence of a Richmond fauna from this section of New York is then to be accounted for by the changes in conditions of sedimentation rather than by an hiatus at the close of Lorraine time. There is a possibility that a fauna closely allied to that of the Richmond may yet be found in New York, in which case it would have an important bearing on the subject. The presence of such a fauna, however, is considered not very probable.

---

[1]*See* Pal. Minn. 1897. v. 3, pt. 2, p. ciii.

Note.—Grabau states, "If no unconformity exists between the Upper Richmond and the Mayville beds and if the latter are of the age of the Clinton of New York, the lower Medina shales of the Niagara region resting upon the Lorraine, must be of Richmond age." N. Y. State Mus. Bul. 92. 1906. p. 124.

[2]The value of subsidences and emergences as a basis for stratigraphic classification is stated by Ulrich and Schuchert in the annual report of the New York State Paleontologist for 1901, p. 659.

UPPER SILURIC AND LOWER DEVONIC FORMATIONS OF THE SKUNNEMUNK MOUNTAIN REGION

BY

C. A. HARTNAGEL

Introduction

The Upper Siluric and Lower Devonic formations of the Skunnemunk mountain region, in the vicinity of Cornwall,[1] Orange co., N. Y., are the extreme northeastern portion of a great outlier of rocks which extends from near Cornwall station southwestward into New Jersey for a total distance of about 50 miles.

The general structure of the rocks of this area is that of a great syncline which is, however, much modified by secondary folds and by faulting. The trend of this syncline is parallel to, and 23 miles southeast from, the main area of the formations of similar ages, which outcrop approximately along a line extending from Rondout, N. Y., southwesterly through Port Jervis and continuing into New Jersey.

Near the northern extension of Skunnemunk mountain, the Moodna river flows in a direction a little north of east. On reaching the end of the mountain, the river abruptly turns and flows southeasterly, in what is apparently a fault valley and across the strike of the Upper Siluric and Devonic formations. The river then again turns and flows towards the northeast and finally empties into the Hudson river at Cornwall-on-the-Hudson.

Within the V-shaped area made by the somewhat unusual course of the Moodna river, there is a comparatively small syncline, and it mainly is to this section that this paper will be restricted.

Previous work on this area. The rocks of this section have been differentiated since the early days of the New York State Geological Survey. Forming as they do an outlying area, they have naturally offered to the geologist an opportunity for careful comparative stratigraphic and paleontologic work. Horton was the first to give an account of this district [An. Rep't.

[1]Idlewild is the name of the postoffice at Cornwall station on the Newburgh branch of the Erie Railroad. This station is but a few hundred yards from the cut on the Ontario and Western Railroad. The nearest station of the latter road is at Orr's Mills less than $\frac{3}{4}$ mile away.

1st Dist. 1839. p. 151]. Later his views are quoted and discussed by Mather.[1] Prof. W. B. Dwight[2] has studied the region, specially the locality of the Townsend iron mine, to which reference will be made later. N. H. Darton,[3,4] in two papers, has given in detail some of the features of this area, and specially a good account of the New Scotland (=Delthyris shaly) fauna. Dr H. Ries[5] and E. C. Eckel,[6] have also briefly discussed the region. Recently Kümmel and Weller[7] have published a section of the formations exposed in the cut near Cornwall station.

The work to which this paper relates was taken up, partly with a view to the determination of interesting, though unexplained, conditions of overlap or faulting which had been noted by previous writers, and partly for the study of some of the Upper Siluric strata of whose age here as in other sections of the State there has been ground for some uncertainty. In carrying on this work the writer has had the advantage of suggestions and advice from Dr A. W. Grabau of Columbia University. To Dr C. P. Berkey, also of Columbia, are due thanks for assistance in the determination of field measurements and structural features.

Structure of the syncline. In the cut of the Ontario and Western Railroad, the syncline can be best observed. Here the distance between the top of the Shawangunk conglomerate as developed in the two limbs of the syncline is less than 500 yards. In the east cut the dip does not vary more than 2° from the vertical and the strike is n. 9° e., while in the west cut the dip is 75° s. e. and the strike is n. 40° e. The strike of the rocks as thus measured in this cut indicates a rapidly spreading syncline. In following along the strike of the outcrops, for ¾ mile, it is found that the limbs of the syncline are ⅔ mile apart and that, with the exception of some local changes where faulting has occurred and to which reference will be made later, the dip of the rocks has varied little from that observed in the railroad cut. From the nature of the fold, the rocks as shown in the cut can extend but a short distance to the northeast. The topographic relations indicate that they soon fail and the underlying rock is the "Hudson River" shale.

To the southwest, after about a mile, the formations of the syncline as exposed in the cut disappear in the low swampy ground. At about the point where the lower formations fail,

[1] Geol. N. Y. 1st Dist. 1843. p. 351, 362, 400.
[2] Vassar Brothers Inst. Trans. 1883–84. 2:74.
[3] Am. Jour. Sci. 1886. 31:209–16
[4] Geol. Soc. Am. Bul. 1894. 5:379–80.
[5] N. Y. State Geol. 15th An. Rep't. 1898. p. 426–28.
[6] N. Y. State Geol. An. Rep't. 1900. p. r147–49.
[7] N. J. State Geol. An Rep't, 1901. 1902. p. 17.

Plate 1

Vertical strata, east limb of syncline, in cut of Ontario & Western railroad, Cornwall station, N. Y. Rondout waterlime at left, Cobleskill and Decker Ferry formations at the right

midway between the outer faces of the syncline, the Oriskany and Cornwall (=Monroe) formations rise as a high elevation known as Pea hill. This hill extends about a mile to the south where, at its base, the Moodna river flows and which, as already indicated, cuts off this area from Skunnemunk mountain.

At first sight it would appear that this trough is a pitching syncline, and its present condition produced as a result of greater erosion of the northeast end which here would bring the two limbs close together. This, however, can be regarded as only one of the factors which indicate a spreading fold. The nearly vertical strata in the railroad cut are conditions which could not have been brought about by any method of erosion alone, but it must be concluded that the narrowness of the fold at one end is indicative of an originally spreading fold and, therefore, that its present appearance is not due simply to erosion.

As the axis of this fold passes considerably to the east of the axis of Skunnemunk mountain, it is regarded rather as a local development and not an extension to the northeast of the main syncline which forms Skunnemunk mountain.

Geological formations. The rocks involved in this area from the top downward are as follows:

Cornwall (=Monroe shales of Hamilton age)		Devonic
Oriskany sandstone		
Port Ewen (?) limestone		
Becraft (?) limestone		
New Scotland limestone		
Coeymans limestone		
Manlius limestone		Upper Siluric (Ontaric)
Rondout waterlime		
Cobleskill and Decker Ferry limestones		
Binnewater quartzite	=Longwood shales of Darton	
High Falls shale		
Shawangunk conglomerate		

"Hudson River" shales.........Lower Siluric (Champlainic)

Cornwall shale. For reasons stated below, this term is used in place of the name Monroe shales which was introduced by Darton[1] to designate the shales carrying a sparse Hamilton fauna, which are well developed in the towns of Monroe and Cornwall in Orange county. In view of the fact that the name "Monroe beds" had been used by Dr A. C. Lane to include all the rocks between the Niagara and Dundee limestones of Michigan, and also since there was some doubt as to the validity of the Michigan name, Professor Prosser submitted the matter to

[1] Geol. Soc. Am. Bul. 1894. 5:374.

the Committee on Geologic Names of the United States Geological Survey, which sent the following reply[1]:

The Committee on Geologic Names on May 12th took action on the validity of the term Monroe in several publications of 1891, 1892 (1893), and 1895, as the name of a group of rocks distinguished in southern Michigan, as against the standing of the name published in 1894 for a shale formation in southeastern New York.

The committee recommended that the Monroe group of southern Michigan should retain the name, and this action has been approved for official publications of the geological survey.

The conclusion was reached on the ground that priority and prescription, or established usage, are combined in the Michigan application of the term in such a way as to make its continued use more desirable than that of Monroe shale in New York; but the case was not considered one in which priority was so definitely obvious as to justify the conclusion on the ground of the publication of 1891-92 (1893) only, since in that publication the definition was inadequate.

The Cornwall[2] shales are well shown at Pea hill where they have a thickness of at least 200 feet. They here appear as two steep ridges, which seem to conform to the synclinal structure of this area and form the highest points on the map east of the Moodna river. These shales are dark gray in color and in places a pronounced slaty cleavage is shown. The number of fossil species found in them is small, but the number of individuals of the same species is quite large. The best localities for collecting are in the old vineyard and the woods on the south side of the east cliff, and on the steep western face of the west cliff. The fossils found are usually distorted and not well preserved. Darton[3] mentions a locality on the south side of Pea hill where is an inconspicuous outcrop of fine grained red and gray sandstone in which the following genera were observed:

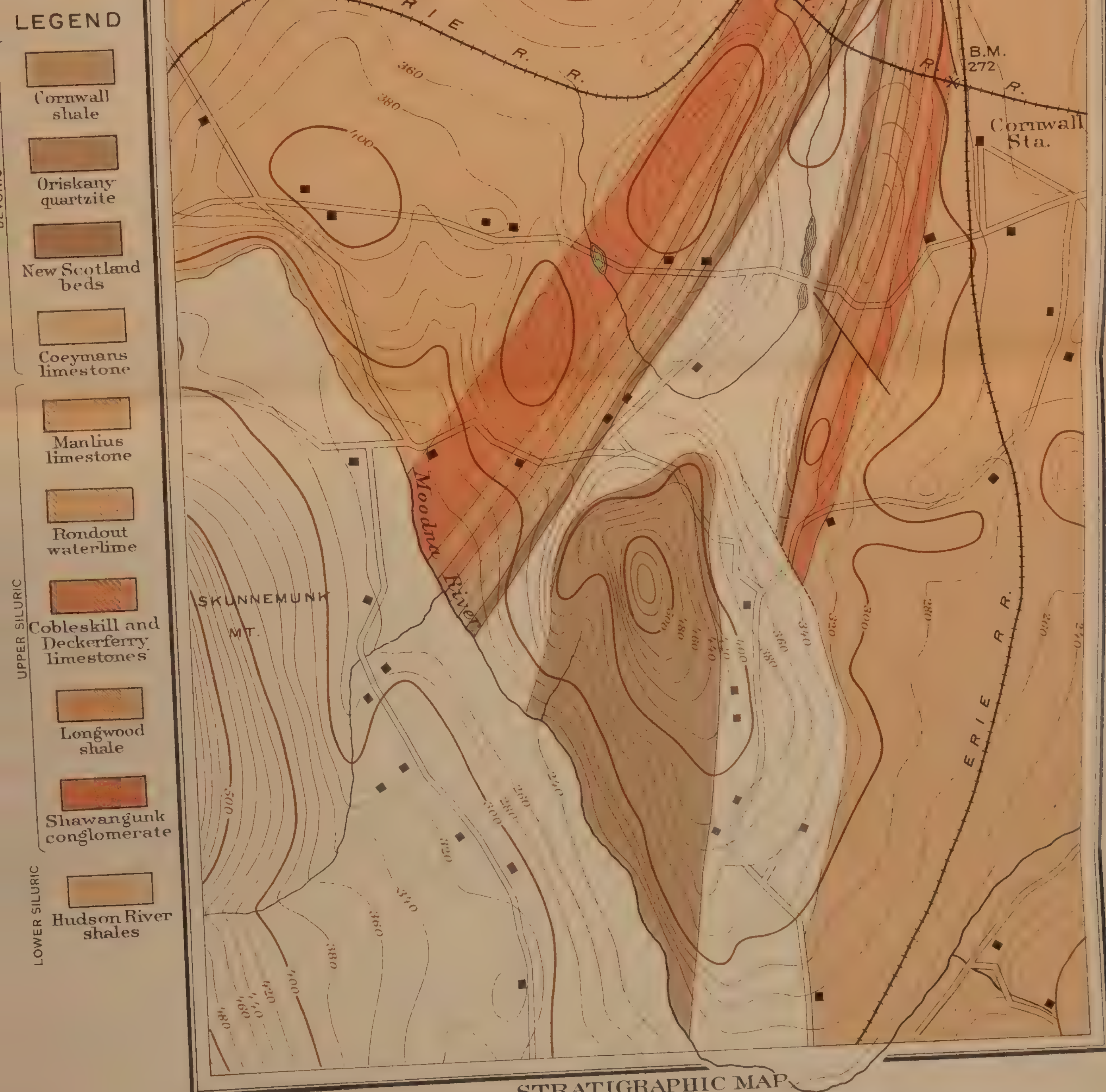
1 Chonetes
2 Meristella
3 Orthis
4 Rhynchonella
5 Spirifer
6 Tentaculites
7 Theca

Oriskany formation. So far as is known the Oriskany lies directly below the Cornwall shales in Pea hill. The contact between these formations at this place has not been observed, so it is at present impossible to tell the exact nature of the rock which directly overlies the Oriskany. In New Jersey, Kümmel

[1]Geol. Sur. Ohio. 1905. Ser. 4. Bul. 7, p. 26.

[2]The expression Cornwall limestones has been used by Eckel to designate the limestones of this area which in age range from the Decker Ferry to the New Scotland. He says, "the term 'Cornwall limestones' is not here proposed as a formation name, but is used merely as a convenient designation for the series till further field work shall have decided the extent to which subdivision can be carried." N. Y. State Geol. An. Rep't. 1900. p. r148.

[3]N. Y. State Geol. 15th An. Rep't. 1895. p. 417.



Geology by C. A. Hartnagel

STRATIGRAPHIC MAP
OF THE
REGION ABOUT CORNWALL STATION
ORANGE COUNTY

0 ½ mile

and Weller[1] have designated as the Newfoundland grit, a formation which is transitional into the Cornwall shale and which has an estimated thickness of about 215 feet. The fauna[2] of this grit is essentially that of the Onondaga limestone of New York. The Newfoundland grit[3] as defined by Kümmel and Weller is as yet known only in the Green Pond mountain region.

The relations between the Newfoundland grit as defined by Kümmel and Weller and the Oriskany quartzite of the Skunnemunk mountain region is not entirely clear. In the New Jersey section under consideration, none of the Helderbergian rocks are shown, the highest known formation below the Newfoundland grit being the Decker Ferry beds, the upper part of which corresponds to the Cobleskill limestone. For the New York area I have retained the name Oriskany quartzite, which term has been used by Darton and by Ries for this quartzite in this region. For the present at least the retention of this term seems the most desirable, for the Helderbergian rocks, if not in actual contact with the Oriskany, are but a short distance below it. Moreover the quartzite at Pea hill is characterized by such Oriskany species as Anoplia nucleata Hall, and Leptocoelia flabellites Conrad. According to Kümmel and Weller the Newfoundland grit grades upward into the Monroe shales, without any line of demarkation. Two species from the Newfoundland beds, Pterinea flabellum Conrad and Actinopteria decussata Hall, as identified by Kümmel and Weller are Hamilton forms and they tend to show a close relation of these beds to the Hamilton formation. It is possible that future studies will indicate that the formation which I have here designated the Oriskany may represent a later return of Oriskany conditions and its fauna.

In this connection it should be noted that the Esopus, Schoharie and Marcellus formations which in the typical New York sections lie between the Oriskany and Hamilton formations, have as yet not been observed in the Skunnemunk mountain region.[4] The section that approaches most closely to the conditions of the Oriskany as found in the Skunnemunk region, both as regards nature of sediments and relation of the overlying rock, is that of central and western New York, which also includes the type section for the Oriskany sandstone. There the Oriskany, wher-

[1]Geol. N. J. An. Rep't. 1901. p. 18.
[2]N. J. Geol. Sur. Rep't on Paleontology. 1902 (1903). 3:105.
[3]The term Newfoundland quartzite was first proposed by Eckel for the quartzite typically exposed at Newfoundland, N. J. Eckel considered the rock to be paleontologically equivalent to the Oriskany quartzite. See N. Y. State Geol. An. Rep't. 1900. p. 1148.
[4]See Ulrich & Schuchert, N. Y. State Pal. An. Rep't. 1901. p. 654.

ever found, is always followed by the Onondaga limestone and west of Syracuse rests upon the Upper Siluric strata. The variations of the silicious and calcareous sediments and of the varying thicknesses along different meridional sections, as also the conditions of sedimentation and distribution of the fauna of the Oriskany of New York, have been stated in detail by Clarke.[1]

The Oriskany formation in the area studied outcrops at the highway which crosses the north end of Pea hill and extends into the fields below. It has a thickness of at least 50 feet and it may be much thicker. The beds are light gray in color and very massive and in some of the layers pebbles are abundant. The rock is very hard and fossils are few and not readily obtained. The following have been recorded by Darton from this locality:

Anoplia nucleata *Hall*	Leptaena rhomboidalis *Wilckens*
Leptocoelia flabellites *Conrad*	Stropheodonta, *sp ?*

Port Ewen and Becraft limestones. These formations, which normally come in between the Oriskany and the New Scotland beds, are not definitely known in this section. There is a covered space between the New Scotland and the Oriskany, but the ground is mostly low and swampy and not favorable for determining the nature of the intervening formations. There are, however, a few outcrops which doubtfully may be referred to the Becraft. The structural relations in this area, between the Oriskany and the New Scotland beds, suggest that faulting may have taken place.

New Scotland limestone. This formation is exposed in both limbs of the syncline. In the west one there are small exposures in the woods south of the railroad cut. In the east limb it is exposed at several places and specially where pits have been dug for limonite, to which reference will be made later. This formation is the highest that can be observed for ¾ mile south of the railroad, the interval between it, as exposed in the two limbs of the syncline, being occupied by a swamp. The entire thickness of the formation could not be measured, but its exposed thickness is not less than 40 feet. These beds are very fossiliferous and shaly, and from ½ cubic meter of shale Darton[2] collected more than 40 species.

Coeymans limestone. This formation is but obscurely shown in the west limb of the fold. There is a small exposure in a depression just south of the railroad. Other unimportant exposures are seen in the woods beyond. The formation is best shown

---

[1] N. Y. State Mus. Memoir 3. 1900. p. 65, 75, 78.
[2] Am. Jour. Sci. 1886. 31: 214.

in the east cut where its thickness is 40 feet. This probably represents the entire thickness, as the upper portion begins to show New Scotland characteristics. The upper part is a very coarse, porous, cherty limestone and contains abundant fossils. The lower part is not so cherty and has more of the aspect of the Manlius, though it also has many fossil remains. Near the base of the formation the rock contains fragments strikingly similar to the Manlius. This is of special interest as the base of the Coeymans marks the lower limit of the Devonic. Other outcrops of the Coeymans can be seen near the highway which crosses this formation farther south. It also shows in some excavations that have been made for limonite and in a small quarry south of the highway above mentioned. A little beyond this quarry the Coeymans and all the lower formations down to the Longwood shales are cut off by faulting.

Manlius limestone. This formation has a thickness of 7 feet. It here appears as a massive limestone, but otherwise has the features of the Manlius. The thinness of the formation in this section is unusual and from the fact that the base of the Coeymans contains fragments of what appear to be Manlius and also from the small thickness one is led to believe that the upper part of the Manlius has been eroded before the deposition of the Coeymans. The studies of Dr Grabau[1] at Becraft mountain indicate that the change from the Manlius to the Coeymans was a gradual one. Similar results have been reached by the study of the Manlius in New Jersey and central New York. Van Ingen and Clark[2] give evidence to show that the Manlius was slightly eroded before the deposition of the Coeymans. Fossils are rarely found in the Manlius as exposed in the cut. Holopea antiqua Vanuxem is the most characteristic, while Leperditia alta Conrad and Tentaculites gyracanthus Eaton are occasionally seen. The Manlius extends south to the fault previously mentioned. The contact with the Coeymans may favorably be seen in a small quarry south of the highway. The Manlius has not been observed in the west limb of the syncline.

Rondout formation. This is rather a massively bedded limestone with some thin partings of shale. The formation is 13 feet thick and at about the middle there is a very sandy layer about 1 foot thick. This layer shows cross-bedding and although slight it is very distinct. The upper part of this formation shows the distinctive sun cracks of the Rondout as

[1] N. Y. State Pal. An. Rep't. 1902. p. 1052–54.
[2] N. Y. State Pal. An. Rep't. 1902. p. 1186.

exposed at many other places in the State. Some Favosites were found in the Rondout at the railroad cut. The lower part of the formation is transitional into the beds below and in one of the beds near the base of the Rondout there is an abundance of Cladopora rectilineata Simpson, a fossil very characteristic of the Cobleskill limestone of eastern New York and New Jersey.

Cobleskill and Decker Ferry limestones. The Cobleskill limestone was formerly correlated as Niagaran, but it is now known to be above the Salina. In this cut the Cobleskill and Decker Ferry formations will be described together since for lack of fossils it is not easy to state where the division between them should be drawn. The total thickness of these two formations is 35 feet. The upper 30 feet are characterized by the great abundance of the small coral Cladopora rectilineata Simpson which gives to the rock a mottled appearance. Fossils other than the corals were not found. This coral, it should be observed, is also very abundant in the Cobleskill and Decker Ferry at the Nearpass section in New Jersey. In color the rock is of various shades of brown. There are seams of shaly matter between some of the more massive beds. The upper 10 feet are finer grained and more subject to fracture and shattering. The lower 20 feet are more silicious and compact and in position correspond with the Rosendale cement bed as shown in Ulster county. The lower 4 feet are characterized by the absence of corals and by the presence of the following species:

Atrypa reticularis *Linne*
Camarotoechia litchfieldensis *Schuchert*
Chonetes jerseyensis *Weller*

Longwood shale (High Falls shale and Binnewater quartzite). This term was introduced by Darton[1] to designate the red shales and light colored quartzites which in the region under consideration and in that extending farther southwestward into New Jersey, occupy a position between the Helderberg (=Decker Ferry in part) limestones and the Shawangunk conglomerate (=Green Pond). Darton states [p. 382]: "There are similar shales having the same relations in Ulster county, N. Y., where they have been considered equivalent to the Clinton formation." In 1894 Darton[2] published a section in Ulster county where the red shales above the Shawangunk conglomerate were designated the Medina and the name Clinton was used for the quartzites above the red shales. As the names Medina and Clinton were

[1]Geol. Soc. Am. Bul. 1893. 5: 382.
[2]N. Y. State Mus. 47th An. Rep't. 1894. p. 530, fig. 8.

shown to be no longer applicable to the formations bearing these names in eastern New York, the writer has used the terms High Falls and Binnewater for Medina and Clinton respectively.[1]

The Binnewater quartzite has generally been considered as of Clinton age. This correlation was made partly on account of its similarity to some of the Clinton beds in central New York and also from the fact that both it and the green Brayman shales formerly supposed to be of Clinton age and which underlie the Cobleskill limestone at Schoharie, contain iron pyrites.[2] The reasons for regarding the Binnewater quartzites as of a later age than the Clinton have been stated in previous publications.[3,4]

The Binnewater quartzite is not well developed in the railroad cut at Cornwall. Under the description of the Longwood red shales Darton states[5]: "In this cut, which is their northernmost exposure, the upper members are light colored, thin bedded quartzites, which have a thickness of 12 feet, and closely resemble the quartzites similarly lying between the waterlime and red shales in the Rosendale cement region of Ulster county." It is evident, however, that of this thickness all but 1 foot belongs to the Decker Ferry formation. Above the red shales there is 1 foot of shaly brecciated limestone, which has the stratigraphic position of the Binnewater quartzite. Immediately above this brecciated layer, characteristic fossils of the Decker Ferry are found, showing that the Binnewater is here represented by a thickness of 1 foot. The brecciated character of this bed indicates a local stratigraphic break which is not so clearly observed in any of the other sections studied.

In Ulster county the change from the Binnewater quartzite to the Wilbur limestone (=Decker Ferry in part), or to the Rosendale cement where the Wilbur is absent, is an abrupt one. This change appears to be due to rapid subsidence which made the shore line at a greater distance and thus the finer calcareous deposits were laid down over the quartzites.[6] The studies made indicate that the Binnewater quartzite was followed closely by the deposition of the overlying limestones. In this connection it is well to note Darton's[7] statement that "The Helderberg (=Decker Ferry in part) limestone usually lies on and merges into the Longwood shales." Kümmel and Weller[8] state: "The

[1]N. Y. State Pal. An. Rep't. 1903. p. 345, 346.
[2]Geol. N. Y. 1st Dist. 1843. p. 354.
[3]N. Y. State Pal. An. Rep't. 1902. p. 1175.
[4]N. Y. State Pal. An. Rep't. 1903. p. 345.
[5]Geol. Soc. Am. Bul. 1903. 5: 382.
[6]See Grabau, N. Y. State Mus. Bul. 92. 1906. p. 125.
[7]Geol. Soc. Am. Bul. 1893. 5: 391.
[8]Geol. N. J. An. Rep't. 1901. p. 41.

passage upward from the conglomerates into the quartzites, thence to the Longwood shales, and finally to the Decker Ferry limestones indicates a gradual but a steady advance of the ocean upon the land to the southeast."

In New Jersey at the Nearpass quarry section, which is just over the State line from Port Jervis in Orange county, N. Y., the Bossardville limestone is just below the Decker Ferry and below the former is the Poxino Island shale. As these two formations lying below the Decker Ferry are not found either in the Skunnemunk mountain region or the Rosendale region, they probably represent, in part at least, a deeper sea facies of the Binnewater quartzite.

In the railroad cut at Cornwall, the High Falls shales are 119 feet thick, and the transition to the Binnewater is well shown. The beds are coarser below and change gradually into the softer shales above. A few thin layers of lighter colored shale are found interbedded in the High Falls, but the shale is mostly a bright red. At the base some of the layers approach closely to a quartzite. Cleavage is often highly developed in the red shales, specially at the Townsend iron mine. The shale breaks into small angular fragments which are very abundantly shown along the southern end of the east limb of the syncline. The High Falls shale is almost nonfossiliferous. The only fossils found were some crinoids stems and several specimens of a small species of lamellibranch. The latter were from the red shale at the Townsend iron mine.

Shawangunk conglomerate. This conglomerate in the Green Pond mountain region of New Jersey has been called the Green Pond conglomerate. In the section studied the conglomerate is well exposed in both limbs of the syncline. The southern end of the west limb of the syncline is a high elevation made up almost exclusively of the conglomerate. The strata are nearly vertical and in places the surface is much worn and polished by glacial action. The measured thickness is 250 feet, which, however, does not represent the entire thickness as a portion of the conglomerate is concealed. The conglomerate is exposed at the railroad cut in both the east and west limbs of the syncline and in the east end of the cut the contact with the High Falls shale can be favorably seen. The conglomerate is characterized near the top by beds of pebbles alternating with beds of red quartzite without pebbles. The pebbles are mostly quartz and many have a diameter of 2 inches. The top of the conglomerate is marked by the last appearance of pebbles. The study of the High Falls

Plate 2

Glaciated hill of Shawangunk conglomerate with vertical strata. West limb of syncline, Cornwall station, N. Y.

and the Shawangunk formations in this cut shows quite clearly that the High Falls shale follows the Shawangunk without break.

The passage from the Shawangunk (=Green Pond) conglomerate to the High Falls (=Longwood) shale is thus expressed by Darton[1]: "They [=High Falls] are also everywhere intimately associated with, and grade into the Green Pond conglomerate." Again [p. 384]: "The quartzites grade upward into the Longwood red shales, and the intergrading is exposed at a number of points along the west slope of Green Pond mountain and in New York. On the northwestern slope of Pine hill, beds of passage are finely exposed, and the red shale and red quartzite are interlaminated for a thickness of several feet." Also [p. 391]: "The Longwood shales are not known to overlap, for they merge into the upper part of the Green Pond rocks in all the exposure." Reference already has been made to the transition of the Shawangunk and the Longwood as stated by Kümmel and Weller.

The following is the section as shown in the east cut near Cornwall station:

		Feet
	DEVONIC	
1	Coeymans limestone	40
	UPPER SILURIC	
2	Manlius limestone	7
3	Rondout waterlime	13
4	Cobleskill and Decker Ferry limestones	35
5	Longwood { Binnewater quartzite / High Falls shale }	120
6	Shawangunk conglomerate	25
	Thickness of the Upper Siluric rocks	200

In all the early work which relates to these formations and until very recently bed no. 4 of the above table, when recognized at all, has been regarded as Niagaran in age. It is thus easy to see that with this correlation of the Cobleskill the lower beds which are the Longwood and the Shawangunk would naturally be correlated with the Medina and Oneida respectively. In the same manner, assuming the Shawangunk to be equal to the Oneida, it would follow that the Cobleskill and Decker Ferry would be regarded as Niagaran. As we now know, however, that the Cobleskill is above the Salina and that all the lower formations follow without any break of importance as has been shown by the work of several writers, it follows that the Long-

[1]Geol. Soc. Am. Bul. 1893. 5:382

wood shales and the Shawangunk conglomerate must be regarded as much later in age than formerly supposed and as has already been suggested, the Shawangunk in this portion of the State represents the invading basal member of the Salina.

Recent determinations have shown that the Oneida conglomerate is no longer to be considered as the basal member of the Medina, but that it belongs to the upper part of the Medina series. This determination in regard to the higher stratigraphic position of the Oneida demonstrates to a certain extent that the Shawangunk is not to be regarded as basal Upper Siluric.[1] The higher stratigraphic position now assigned to the Oneida makes the time interval between the Oneida and the Shawangunk conglomerates less than formerly supposed when the Oneida was considered as basal Medina. Some of the reasons for considering the Shawangunk as of Salina age have already been given. Other reasons are as follows: The Shawangunk conglomerate rests on folded and eroded "Hudson River" strata. That extensive folding and erosion had taken place previous to the deposition of the Shawangunk is shown by the fact that in some places these agents have brought to view exposures of rock which from the faunal contents are regarded as the Normanskill shale of middle Trenton age. The presence of Lorraine beds shows that deposition had continued until the close of the Lorraine and therefore, to allow time for the folding and erosion of the strata previous to the deposition of the Shawangunk, we must regard this conglomerate as of later age than the Oneida. The almost nonfossiliferous character of the strata below the Decker Ferry beds indicates that they were formed during Salina time rather than during the Niagaran period. The period of the Shawangunk conglomerate was one of increasing submergence[2] and on the east side of the Helderberg the succeeding formations progressively overlap the "Hudson River" shales until finally at Becraft mountain the Manlius, the highest member of the Upper Siluric rests unconformably upon the "Hudson River" shales. From these conditions of overlap as shown on both the east and west sides of the Helderberg the evidence is in favor of regarding the Shawangunk as Salina, since the latter on the western side of the Helderbergian barrier extends much farther east than does the Niagaran and in the same way the higher formations of the Upper Siluric are to be looked for in the eastern section.

---

[1]See Grabau N. Y. State Mus. Bul. 92. p. 126.
[2]See Ulrich & Schuchert, N. Y. State Pal. An. Rep't. 1901. p. 647.

TABLE SHOWING RELATIONS OF THE UPPER SILURIC SECTIONS OF EASTERN NEW YORK WITH THE WESTERN NEW YORK SECTION

Western New York	Port Jervis, Orange co.	Ulster co.	Cornwall, Orange co.	Previous correlation for Eastern New York and New Jersey
Cobleskill	Cobleskill	Cobleskill	Cobleskill	"Niagara"
Salina series	Salina series	Salina series	Salina series	
Bertie	Decker Ferry	Decker Ferry	Decker Ferry	
Camillus	Bossardville	(Rosendale cement & Wilbur limestone)		
Syracuse	Poxino Island			
Vernon				
Pittsford		Binnewater sandstone	Longwood { Binnewater sandstone	Clinton
	High Falls shale(?)	High Falls shale	Longwood { High Falls shale	Medina
	Shawangunk	Shawangunk	Shawangunk	Oneida
Guelph Lockport Rochester Clinton				
Medina including Oneida at top and Oswego sandstone at base	Unconformity	Unconformity	Unconformity	Unconformity
"Hudson River" beds	"Hudson River" beds	"Hudson River" beds	"Hudson River" beds	"Hudson River" beds

The subdivisions of the Salina series are not intended to show exact stratigraphic equivalents as read horizontally across the page, but rather the subdivisions recognized in the different sections.

In Rensselaer county there is a quite extensive plateau underlain by what is known as the Rensselaer grit. This formation has generally been regarded as basal Upper Siluric and correlated with the Oneida conglomerate or the Shawangunk conglomerate, the two latter being regarded as stratigraphically equivalent. If we regard the Rensselaer grit as basal Upper Siluric then this region must have been submerged shortly after the Taconic revolution. This, however, does not appear to be the case since the grit rests unconformably on strata which in age range from Lower Cambric to and including the "Hudson River" beds.[1]

The evidence furnished by the study of the Shawangunk grit and the Oneida conglomerate does not indicate that either of these formations extended as far as the region of the Rensselaer

[1]Dale, T. N. U. S. Geol. Sur. Bul. 242. 1904. p. 51.

grit. There does not seem to be good evidence to show that the sea covered this area after the Green Mountain uplift until later Upper Siluric or Devonic time. This is made apparent when we consider that the Rensselaer grit occupies an area that was highly involved in the disturbances at the close of the Champlainic period.

In tracing the Siluric formations north from Ulster county, the Shawangunk conglomerate is the first to fail, and the succeeding formations fail by overlap in regular order until at Becraft mountain in Columbia county the Manlius as already pointed out rests unconformably upon the Champlainic strata. This shows that as we approach the Rensselaer grit area, only the highest members of the Upper Siluric are present, and the conditions of overlap of these formations clearly indicate that the Rensselaer grit is not of Shawangunk age.

In tracing the Upper Siluric formations eastward from central New York, the Oneida is overlapped by the Clinton, and in Albany county but 17 miles from the Rensselaer grit plateau, the Manlius and a few feet of the Rondout are the only members of the Upper Siluric present. From this it does not appear that the Rensselaer grit can be correlated with the Oneida conglomerate.[1] The submergences and emergences, which involve the conditions of overlap following the Taconic revolution, have been stated in detail by Ulrich and Schuchert.[2]

Structural relations of the Townsend iron mine. The Townsend iron mine was first described by Horton[3] in 1839 as follows: "Two and a half miles west of Canterbury, in Cornwall, is the *hematite* or *limonite* mine of Mr. Thomas Townsend. For the last two years this ore has been considerably used and although a lean ore, it makes excellent iron. It is mostly in powder, or very small fragments, mixed with balls and pieces of the hematite, of a few pounds weight. It lies in a limestone rock, and between the limestone and the grit rock. These rocks where connected with the ore, are decomposed to great extent, and mixed in a state of powder with the ore; hence the ore requires washing."

This limestone was definitely correlated by Mather [4,5] with what are now recognized as the New Scotland beds. He states, "The Strophomena rugosa Dalman and S. radiata Sowerby are very common fossils at the above locality, and the

[1]See Dale, U. S. Geol. Sur. Bul. 242. 1904. p. 53.
[2]N. Y. State Pal. An. Rep't, 1901, p. 647, 660.
[3]An. Rep't 1st Dist. 1838 (1839) p. 165.
[4]Geol. N. Y. 1st Dist. 1843. p. 351.
[5]See also plate 5, figure 14.

Plate 3

Townsend limonite mine near Cornwall station, N. Y. Longwood red shale at the left, New Scotland beds at the right

rock is considered as belonging to the Catskill shaly limestone, which here has been upturned on its edges like the adjoining slate, grits and other rocks."

An examination of this mine was made by Prof. W. B. Dwight[1] who states, "that the limestones are of the lower Helderberg group, and that the adjoining red sandstone and conglomerate are not of the Triassic, like the New Jersey red sandstone, but are the Oneida conglomerate and the fine grained sandstone of the Medina epoch."

The geology in the vicinity of the Townsend iron mine has been studied in some detail by Darton.[2,3] His reports include the stratigraphic and paleontologic determinations and maps and sections of the region studied are given.

At the Townsend iron mine we find the strata nearly vertical and the New Scotland beds rest against the Longwood shales. This condition was noted by Darton, who states that it was due to faulting or thinning out of the formation below the New Scotland.

In the railroad cut the formations between the New Scotland and the Longwood shales are 95 feet thick. As the Townsend mine is but ½ mile away from this cut and in the same limb of the syncline, it did not seem possible that the formation could thin out in such a short distance. On tracing the intervening formations south from the cut at a short distance south of the small quarry, just beyond the highway, the limestone formation below the New Scotland suddenly ceases and we come upon an area of red shale. The increased thickness of the Longwood shale at this point clearly indicated that they had been faulted. There is a small depression which marks the fault line passing at an angle and meeting another parallel to the strike of the rocks. It is evident that in faulting a wedge-shaped block was forced out carrying the limestone with it, the red shales thus coming into contact with the New Scotland. The steep ridge now left standing is composed of red shales, and it appears that only in very recent times has the limestone cap been removed and thus made possible this steep ridge of red shales. There are other indications of faulting in the vicinity of the mine. In some exposures the rocks are partly overturned and the red shales show induced cleavage. From the red shales at this mine a number of specimens of a lamellibranch were obtained. With

[1]Vassar Brothers Inst. Trans. 1883–84. p. 75
[2]Am. Jour. Sci. 1886. 31: 209–10.
[3]Geol. Soc. Am Bul. 1893. 5: 370.

the exception of fragments of crinoids, these have been the only fossils recorded from the Longwood shales.

The iron taken from this mine is from the New Scotland beds and along the contact of the latter with the Longwood shale. The leached character of the red shales which are adjacent at once suggests the origin of the iron. A brief description of this mine together with the following analysis of the ore is given by Putnam.[1]

	Per cent
Metallic iron	28.57
Phosphorus	0.240
Manganese	Present
Phosphorus in 100 parts iron	0.840

A study of the geological relations at the mine shows that the presence of iron ore in the New Scotland beds is of local occurrence and is found only where the New Scotland beds are in contact with the Longwood shales. Several openings in the New Scotland beds north from the mine, have been made, but without finding any ore. An examination of these nonproductive openings shows that between them and the Longwood shale there are at least 80 feet of limestones, which indicates that this part of the syncline has not been affected by the faulting and that further exploitation for iron, of the New Scotland beds north from the productive mine will bring only negative results.

[1] Mining Industries of the U. S. 1886, p. 127.

MINERALS FROM LYON MOUNTAIN, CLINTON COUNTY

BY[1]

HERBERT P. WHITLOCK

Early in the spring of 1905 the attention of the writer was directed by Mr H. H. Hindshaw, geologist to the Delaware & Hudson Company, to some interesting occurrences of secondary minerals associated with the magnetite deposits of the Chateaugay mines at Lyon Mountain.

A visit to the mines made in the following summer resulted in the addition to the collection of the New York State Museum of about 150 specimens from this locality. This material augmented by a smaller collection made by Mr D. H. Newland, Assistant State Geologist, and a number of fine specimens presented to the museum as well as some loaned for study by Mr Hindshaw, forms the basis of the following paper. The writer wishes to express his thanks to the above gentlemen as well as to Thomas Cameron, at that time underground foreman, for many valuable suggestions as well as for aid in acquiring material.

GENERAL DESCRIPTION

The Chateaugay mines are situated at Lyon Mountain in Clinton county, about 23 miles west of Plattsburg and near the northern boundary of the area of Adirondack gneiss which forms the main outlying mass of the Adirondacks. The workings consist of a series of inclined shafts which in some instances extend to a vertical depth of 800 feet. It was for the most part in the deeper levels of the mine that the openings or "vugs" were encountered which furnished the greater mass of the material collected. One of the largest of these now accessible, situated at the 600-foot level, was some 15 feet in length by 3 feet wide and extended vertically to an unknown hight, the bottom being filled with blocks fallen from above. The walls of this cavity, where accessible, were thickly covered with hornblende, apatite, orthoclase and titanite in large and perfect crystals as well as many of the minerals later to be described, in matrix. Most of the calcite specimens of types III, IV and V were obtained from a still larger vug which formerly

extended across the ore body and was excavated previous to the writer's visit. Most of the material collected from the dump heaps also showed evidence of the same vug formation.

MINERAL SPECIES

Molybdenite

Molybdenite occurs closely associated with brown titanite in one of the smaller vugs opened on the 800-foot level close to no. 5 shaft. The specimen obtained showed one bent and distorted crystal about 10 mm in diameter as well as several smaller ones, from which latter imperfect measurements were obtained which served to establish the presence of the pyramid ($20\bar{2}1$). This pyramid, as shown by Moses,[1] is of comparatively frequent occurrence on measurable crystals of molybdenite, being found on the crystals from Frankford, Pa.; Aldfield, Quebec; Cape Breton, and Okanogan county, Washington. The amphibole, titanite, phlogopite and quartz associated with the Lyon Mountain molybdenite showed marked evidence of partial resolution and were accompanied by secondary calcite, stilbite and pyrite.

Pyrite

Pyrite occurs abundantly in detached crystals of secondary origin associated with the orthoclase, hornblende, quartz and magnetite of the wall rock in the contact zone with the ore body. They consist of small but brilliant individuals averaging about 2 mm in diameter, the principal faces of which yield excellent reflections.

The examination of a large number of these failed to reveal any new or unusual forms, the prevailing habit being that shown in figure 1 which is identical with that found on the pyrite from Kingsbridge.[2] The occurring forms are *a* (110), *o* (111), *e* (210), *s* (321) and *n* (211), the two latter being present only as narrow faces.

Quartz

Quartz of both primary and secondary derivation occurs abundantly in the contact zone. The primary quartz occurs in rounded masses of variable size deeply furrowed and completely covered

[1] Moses, A. J. Crystallization of Molybdenite. Am. Jour. Sci. 1904. 167: 359.
[2] Moses, A J. Pyrite crystals from Kingsbridge. Am. Jour. Sci. Ser. 3. 1893. 45: 488.

with parallel systems of wavy lines due to partial resolution. Several of these etched nodules which were obtained in a calcite matrix represented originally detached crystals. These roughly presented the form of oblate spheroids and though extremely rough on the surface reflected back the light from minute smooth surfaces in a manner suggesting the appearance of a cleavage fragment. On orienting one of these nodules in the reflection goniometer, it was found that the reflections from these corrosion surfaces in the circle of the transverse axis gave the angles of the prismatic zone for quartz. Furthermore, on reorienting the nodule, reflections were obtained from corrosion faces corresponding to the rhombohedral planes *r* $(10\bar{1}1)$ and *z* $(01\bar{1}1)$ the angles agreeing fairly well with theory, considering the character of the faces measured.

Secondary quartz occurs with hematite, calcite and byssolite, all of later generation and derived from the redeposition of dissolved primary minerals, in brilliant crystals, transparent and for the most part colorless, but occasionally showing slight smokiness as well as inclusions of scaly hematite and prochlorite. A number of crystals were measured, several of which showed the rhombohedron Γ $(40\bar{4}1)$ and the trapezohedrons *x* $(51\bar{6}1)$ and *q′* $(10.1.\overline{11}.1)$ the two latter being observed on right-handed crystals. In one instance a right trapezohedron was noted in the zone $[01\bar{1}0.11\bar{2}1.10\bar{1}1]$ which gave an angle corresponding to $(12.11.\overline{23}.11)$ but as the face was not repeated on the same or other crystals, its accidental presence was assumed to be due to vicinal development. Figures 2a–2b show this habit.

The observed forms with the measured and calculated angles are given below:

	Forms	Angle	Measured		Calculated	
m	$10\bar{1}0$					
r	$10\bar{1}1$					
z	$01\bar{1}1$		°	′	°	′
Γ	$40\bar{4}1$	$10\bar{1}0:40\bar{4}1$	11	11	11	8
S	$11\bar{2}1$	$10\bar{1}0:11\bar{2}1$	37	51	37	58
x	$51\bar{6}1$	$10\bar{1}0:51\bar{6}1$	11	58	12	1
q′	$10.1.\overline{11}.1$	$10\bar{1}0:10.1.\overline{11}.1$	6	33	6	31½

Hematite

Secondary hematite derived from the magnetite occurs associated with other minerals of the second generation such as quartz, calcite and albite. It is found in close aggregates of brilliant metallic plates of the type shown in figure 3 the observed forms being *c* (0001), *r* $(10\bar{1}1)$ and *n* $(22\bar{4}3)$. A phase of this habit found in close association with the secondary amphibole (byssolite), is characterized by minute circular disks about 1 mm in diameter consisting of flat rosettes of thin plates. These have a red metallic luster resembling that of burnished copper and show bright cherry-red by strong transmitted light. A specimen of quartz with which these latter were associated was quite thickly covered with small hemispheres of botryoidal hematite. It is quite evident from this specimen [pl. 8] that these three phases of the deposition of hematite belong to the same period of genesis and were deposited toward the end of the formation of secondary quartz.

Calcite

The several phases which mark the deposition of secondary calcite are characterized by calcite crystals of definite habit. Of these crystal types, the first two stand distinctly apart from a genetic point of view, whereas the last three are more or less closely related both from the standpoint of crystal genesis and habit.

Type I. Crystals of this type are found directly associated with the corroded quartz orthoclase and amphibole, in most instances deposited as a crust upon a highly corroded surface. They are distinctly scalenohedral in habit, the steep scalenohedron μ $(54\bar{9}1)$ predominating, modified in termination by the rhombohedrons *M* $(40\bar{4}1)$ and *E* $(0.13.\overline{13}.4)$. Figures 4a-4b and 5a-5b show this habit. The rhombohedron *M* is present in a bright series of planes which furnished excellent points of reference. The rhombohedron *E*, on the other hand, gave faint but distinct reflections from a series of dull and somewhat rounded surfaces. On several specimens the rhombohedron *r* $(10\bar{1}1)$ is prominent in crystals of this habit. Several times during the measurement of crystals of this type, a narrow plane beveling the acute polar edges of μ $(54\bar{9}1)$ was observed. A rhombohedron in this zone would have the indexes $(0.13.\overline{13}.2)$ a form which seems doubly probable in consideration

of the fact that the presence of $(0.13.\overline{13}.4)$ has already been noted with reference to this type. No satisfactory reading could, however, be obtained.

The crystals which measure from 3 mm to 25 mm in length are, in some instances, filled with microscopic inclusions of quartz, hematite and matted byssolite, the latter forming a central nucleus of irregular shape, while the hematite, which was connected with a later stage of the crystal growth, appears in the outer layers in dendritic bunches.

Regarding the generation of calcite of this type it must be unquestionably placed at the base of the calcite series as shown at Lyon Mountain. The marked absence of pyramidal forms in the crystal habit and the presence of two modifying rhombohedra entirely absent from the varied types found in the later calcite deposition, set it distinctly apart as marking a separate genetic phase. At the same time the close association with primary minerals which show evidences of corrosion, points to the origin of this type from a highly corrosive crystallizing solution, rich in carbonate of lime but still far from saturated with silica and iron.

Type II. Calcite crystallizing in the forms of type II occurs incrusting the surface of joints in the ore body, in a confused aggregate of translucent, milky white crystals which exhibit none of the tendency toward parallel grouping of separate individuals noticeable in other types from this locality. The manner of the crystal massing suggests rapid deposition from a solution whose condition of concentration had been influenced by sudden cooling, change of pressure or some allied cause. Such a change of condition of concentration seems highly probable in the case of an open joint filled or partly filled with the crystallizing solution which from the nature of the case would be far more sensitive to the influence of currents.

The crystals of this type [fig. 6a–6b] which average 7 mm in diameter, are rhombohedral in habit and composed of "built up" forms, the predominating negative rhombohedron being deeply grooved by incipient modifications parallel to (0001) and $(01\overline{1}2)$. The rhombohedron Y $(0.19.\overline{19}.13)$ is present as a series of moderately brilliant but somewhat rounded faces; the form was determined by averaging the readings taken on 20 of the best crystals available. The scalenohedron **q**: $(2\overline{4}61)$ is present, beveling the

basal edges of the predominating rhombohedron. Indications pointed to a second scalenohedron in this zone giving the indexes $(10.16.\bar{26}.3)$ and beveling the basal edges of $\mathfrak{q}$: as thin lines from which measurements were obtained with great difficulty. The form must be regarded as doubtful.

Type III. Calcite crystallizing in forms of this type differs from those previously described both in mode of occurrence and habit. They occur for the most part embedded in masses of byssolite and are often free or so loosely attached that doubly terminated individuals are readily obtained. They are of a later generation than those of type I, being contemporary and closely associated with secondary quartz, hematite and albite derived from the minerals accompanying type I. In habit they are essentially pyramidal, the simpler development showing the predominance of two pyramids in the same series, $(8.8.\bar{16}.3)$ and $(22\bar{4}3)$ figure 7a, 7b. More complex variations of this habit [fig. 8a–8b] are found associated with these secondary minerals and, indeed, the remaining types to be discussed may be said to represent phases of the same conditions of deposition, as they are, at the same time, modified expressions of the same crystal habit. The combination shown in figure 7a, 7b represents this habit in its simplest development and is found in crystals varying from 2 to 5 mm in vertical length. The pyramid γ $(8.8.\bar{16}.3)$ occurs as a series of bright, sharp faces. The faces of the pyramid Γ $(22\bar{4}3)$ and of the rhombohedron Υ $(0.19.\bar{19}.13)$ are of fair brilliancy but frequently roughened by natural etchings. The planes of v $(21\bar{3}1)$ are often present on this combination but of relatively small development. On two crystals a terminating scalenohedron in the zone $[0.19.\bar{19}.13.19.\bar{19}.0.13]$ gave measurements roughly corresponding to $(7.2.\bar{9}.11)$ but on account of the imperfect nature of the reflections the form must be regarded as doubtful.

The combination shown in figure 8a-8b represents a modification of this habit in which the planes of the scalenohedron v $(21\bar{3}1)$ partly replace those of γ and a second negative rhombohedron l $(0\bar{4}45)$ terminates the crystal partly replacing the planes of Γ. The alternate polar edges of γ are beveled by the scalenohedron $\mathfrak{U}$: $(14.12.\bar{26}.5)$ in the zone $[8.8.\bar{16}.3.\bar{16}.8.8.\bar{8}.3]$. This combination which seems to indicate a slower and more perfect stage of crystallization occurs in larger crystals than that previously described under this type, detached crystals measuring from 4 mm to 30 mm in vertical length.

Type IV. Figures 9a–9b show a combination resulting from the development of the negative rhombohedron A $(04\bar{4}3)$ which here replaces the planes of the pyramids γ and Γ to the extent of giving to crystals of this phase a rhombohedral aspect. The pyramids γ $(8.8.\overline{16}.3)$ and Γ $(22\bar{4}3)$ which connect this combination with type III are present as faces of great brilliancy, as are also the planes of v $(21\bar{3}1)$. The rhombohedron A $(04\bar{4}3)$ here replaces Υ as a series of brilliant planes which yield excellent reflections. Genetically this type corresponds closely with type III, the crystals occurring with considerable secondary quartz embedded in chlorite also of the second generation. The crystals are clear and faintly yellow in color and measure from 6 to 10 mm on the vertical axis.

A curious variation of this type was noted on a large mass of hornblende which was thickly incrusted with albite crystals.[1] These calcite crystals were symmetrically disposed in parallel position on the six basal angles of a positive rhombohedron r $(10\bar{1}1)$ the latter evidently of a previous growth and considerably etched and roughened on the surface. One of these composite crystals is shown in figures 10b–10c and an enlargement of one of the superposed secondary crystals in figure 10a. The secondary crystals of this phase bear a general resemblance to the modified combination of type III [figures 8a-8b] in that they show the scalenohedron 𝔘: $(14.12.\overline{26}.5)$ beveling the alternate polar edges of the prevailing pyramid γ $(8.8.\overline{16}.3)$. The pyramid π $(11\bar{2}3)$ in the same series with those previously noted appears as a terminal modification consisting of deeply striated faces. The scalenohedron μ $(54\bar{9}1)$ of type I here reappears for the first time as a series of small but brilliant faces. The negative scalenohedron 𝔮: $(2\bar{4}61)$ characteristic of type II is here represented by small brilliant faces; from both of these latter forms, excellent reflections were obtained. These two pyramids Γ $(22\bar{4}3)$ and γ $(8.8.\overline{16}.3)$ are developed as large faces, the former giving fair reflections from somewhat dull surfaces, and the latter bright and sharp reflections. The three pyramids lie well in zone and agree closely as to measured and calculated angles. The composite crystals as shown in figures 10b–10c vary in size from 4 mm to 30 mm in diameter measured on a basal axis. The superposed crystals frequently unite to form a band encircling the primitive rhombohedron which latter in many instances shows incipient forms of this habit irregularly disposed

[1] The writer is indebted to Mr H. H. Hindshaw for the loan of this handsome specimen as well as for material taken from it for study

on the rhombohedral planes in parallel position; these latter, however, are microscopic and only serve to accentuate the characteristic grouping habit.

Type V. Crystals of this type were noted on a single specimen, which differed little, with respect to the association and general deposition of the secondary minerals, from the specimens producing types III and IV, but which showed a much lower percentage of secondary quartz crystals than these latter. Several small crystals of transparent apatite were noted on this specimen. In habit these crystals are far more complex than any hitherto described from this locality, the combination shown in figures 11a–11b consisting of no less than 11 forms. In size and brilliancy they also exceed the previously described types averaging 12 mm in vertical length and beautifully developed in clear and sharp faces, all of which, with the exception of l $(04\bar{4}5)$ gave fine reflections of the goniometer signal. In general, indications seem to connect this type with a slower action of the crystallizing solution producing more perfect and highly modified individuals.

A clearly marked rhombohedral zone consisting of l $(04\bar{4}5)$, A $(04\bar{4}3)$, $f(02\bar{2}1)$, Δ $(07\bar{7}2)$ and Σ $(0.11.\overline{11}.1)$ characterizes the crystals of this type, the faces of which are small but clearly defined. γ $(8.8.\overline{16}.3)$ the predominating pyramid of types III and IV is wholly lacking from this combination, its place being taken by $\propto$ $(44\bar{8}3)$ a form not hitherto noted from this locality but which completes the series of pyramids by supplying a logical link in the sequence between $(22\bar{4}3)$ and $(8.8.\overline{16}.3)$ the former of which is present as a highly developed series of planes giving very fair reflections. Two negative scalenohedrons $\mathfrak{p}$: $(24\bar{6}1)$, which was also noted in types II and IV, and C: $(34\bar{7}2)$ are present as large and well developed forms. The positive scalenohedrons v $(21\bar{3}1)$ and R: $(8.4.\overline{12}.1)$ are present as well developed forms. A regular and symmetrical roughening was noted on the obtuse polar edges of v $(21\bar{3}1)$ as shown in figure 11b which was probably due to some twinning tendency,[1] although no twins were observed in connection with this type.

The complex zonal relations between the various forms occurring on the calcite from Lyon Mountain are shown in the stereographic projection, figure 12 and are particularly well illustrated in the

[1] In this connection it is interesting to note that the calculated values of ϕ for $(2\bar{1}31)$ and $(42\overline{61})$ differ by but 30″ and that consequently a penetration twin parallel to (0001) would bring the superposed planes of these two forms in close orientation and might result in a vicinal roughening similar to that observed.

combinations of type V which includes 11 of the 19 forms observed for the locality. Assuming the principle announced by Cesaro[1] "that when a crystal of calcite is formed around a preexisting crystal, in general the edges of the first crystal tend to be replaced by faces which are parallel to them; i. e. a face of the new crystal is in zone with two faces of the original one." The superposed groups of type IV present a striking instance of harmony in zonal relations, and indeed the gradual increase in the numbers of forms from type I through types III, IV and V shows a close coincidence with Cesaro's principle.

GENETIC RELATIONS

In a former paper[2] the writer has referred to the pyramidal habit of the calcite crystals of Union Springs and has attempted to connect the pyramidal habit with a crystallizing solution heavily charged with dissolved silica. The conclusions drawn from the Union Springs occurrence, where a single pyramid γ $(8.8.\bar{1}6.3)$ was used as a basis of comparison between the Union Springs calcite and that from Rhisnes and Andreasberg, gain added force in the case of Lyon Mountain, where a series of four pyramids occur in the various types, all four of which pyramids are found on the Rhisnes calcites and three of which also occur on the Andreasberg crystals. The dominant form of a combination illustrated by Luedecke[3] under type VIII from Jacobsglück vein, Andreasberg, μ $(54\bar{9}1)$, is identical with the dominant form of type I from Lyon Mountain. He notes this type as occurring sparingly with quartz which latter mineral has a "*hacked, corroded appearance.*" The mine waters from this immediate locality carry considerable gypsum, epsomite, limonite and hematite in solution and give evidence of having been strongly corrosive. These facts are in perfect accord with the conditions noted in connection with type I from Lyon Mountain [p. 59], and it seems highly probable that in the case of the Jacobsglück vein, Andreasberg and the Lyon Mountain localities, the first stage of calcite deposition took place from a highly corrosive solution which was taking up silica while depositing crystals of the steep scalenohedral habit of calcite. The absence of all secondary quartz in connection with this habit in both localities, points to the fact that the primary quartz in both cases was still

[1] G. Cesaro. Les formes crystalline de la Calcite de Rhisnes. Ann. de la Soc. Geol. de Belgique. 1889. 16:167.

[2] Whitlock, H. P. Calcite from Union Springs, Cayuga county. N. Y. State Mus. Bul. 98, p. 15–16.

[3] Luedecke, Otto. Die Minerale des Harzes, Berlin 1896, pl. XX, fig. 1.

being dissolved and its subsequent appearance with calcite crystals of a later generation, which latter are characterized by an unusual series of second order pyramids seems to connect, beyond question, the pyramidal habit of calcite with a crystallizing solution saturated or nearly saturated with silica.

SUMMARY OF DISTRIBUTION OF FORMS

Letter	Indexes	Type I	Type II	Type III	Type IV	Type V	
π	$11\bar{2}3$				+		
Γ	$22\bar{4}3$			+	+	+	
$\propto$	$44\bar{8}3$					+	
γ	$8.8.\overline{16}.3$			+	+		
M	$40\bar{4}1$	+					
r	$10\bar{1}1$	+					
l	$04\bar{4}5$			+		+	
A	$04\bar{4}3$				+	+	
Υ	$0.19.\overline{19}.13$		+	+			New
f	$02\bar{2}1$					+	
E	$0.13.\overline{13}.4$	+					New
Δ	$07\bar{7}2$					+	
Σ	$0.11.\overline{11}.1$					+	
v	$21\bar{3}1$			+	+	+	
μ	$54\bar{9}1$	+			+		
$\mathfrak{U}$:	$14.12.\overline{26}.5$			+	+		New
$\mathbf{R}$:	$8.4.\overline{12}.1$					+	
$\mathfrak{q}$:	$24\bar{6}1$		+		+	+	
c :	$34\bar{7}1$					+	

SUMMARY OF MEASURED AND CALCULATED ANGLES

Letter	Indexes	Type	Angle	Number of readings	Measured °	Measured ′	Calculated °	Calculated ′
π	$11\bar{2}3$	IV	$11\bar{2}3:2\overline{11}3$	6	28	15	28	39
		IV	$11\bar{2}3:8.8.\overline{16}.3$	1	47	37	47	57
Γ	$22\bar{4}3$	III	$22\bar{4}3:4\overline{22}3$	2	44	2	44	8½
		IV	$22\bar{4}3:4\overline{22}3$	1	44	12	44	8½
		V	$22\bar{4}3:4\overline{22}3$	2	44	10½	44	8½
		III	$22\bar{4}3:8.8.\overline{16}.3$	6	28	48	28	54
		IV	$22\bar{4}3:8.8.\overline{16}.3$	3	28	52½	28	54
$\propto$	$44\bar{8}3$	V	$44\bar{8}3:8\overline{44}3$	1	54	23	54	30
		V	$44\bar{8}3:21\bar{3}1$	2	10	26	10	27

SUMMARY OF MEASURED AND CALCULATED ANGLES (*concluded*)

Letter	Indexes	Type	Angle	Number of readings	Measured		Calculated	
γ	8.8.16.3	III	8.8.16.3:16.8.8.3	3	58	28	58	28
		IV	8.8.16.3:16.8.8.3	1	58	33	58	28
		III	8.8.16.3:8.8.16.3	4	24	37	24	46
		IV	8.8.16.3:8.8.16.3	2	24	40	24	46
M	4041	I	4041:0111	5	31	16½	31	10½
l	0445	V	0445:0111	2	96	46	97	7
A	0443	IV	0443:4043	*a*15	87	13	87	10
		IV	0443:0111	1	82	47	82	38½
		V	0443:0111	3	82	41⅓	82	38½
r	0.19.19.13	II	0.19.19.13:19.0.19.13	10	90	45	90	44
		III	0.19.19.13:19.0.19.13	9	90	31½	90	44
		II	0.19.19.13:0111	10	99	41½	99	51½
		III	0.19.19.13:0111	9	99	49½	99	51½
f	0221	V	0221:0111	3	72	9⅓	72	17
E.	0.13.13.4	I	0.13.13.4:0441	4	148	27	148	28
Δ.	0772	V	0772:0111	1	118	34	118	27½
Σ.	0.11.11.1	V	0.11.11.1:0111	2	50	42	50	39½
v	2131	III	2131:2311	1	75	18	75	22
		V	2131:2311	1	75	15	75	22
		III	2131:3121	3	35	36	35	39
		V	2131:3121	1	35	43	35	39
		III	2131:1231	1	47	17	47	1½
μ	5491	I	5491:5941	7	66	46½	66	42½
		I	5491:9451	10	52	5½	52	11
		IV	5491:9451	1	52	35	52	11
		I	5491:4591	6	16	29	16	30
𝔘:	14.12.26.5	III	14.12.26.5:14.26.12.5	2	63	10½	63	19
		III	14.12.26.5:26.12.14.5	4	53	38½	53	34
		III	14.12.26.5:12.14.26.5	5	25	4½	25	46
		IV	14.12.26.5:12.14.26.5	1	25	48	25	46
ℜ:	8.4.12.1	V	8.4.12.1:12.4.8.1	1	38	4	38	2
		V	8.4.12.1:4.8.12.1	1	24	17	24	21
		V	8.4.12.1:2131	1	15	37	15	30
𝔮:	2461	II	2461:2641	3	80	1	80	1½
		II	2461:6421	5	37	21	37	30
		IV	2461:6421	1	37	38	37	30
		V	2461:6421	3	37	26	37	30
		II	2461:4261	9	30	48	30	39
		IV	2461:4261	2	30	41½	30	39
		V	4261:2131	1	31	42	31	49
c:	3472	V	3472:3742	2	65	34	65	24
		V	3472:4372	2	47	43	47	48½

*a*Measurement made with contact goniometer.

Albite

Albite occurs incrusting orthoclase and hornblende of a previous generation often associated with calcite, secondary quartz and byssolite. The crystals are small, rarely exceeding 5 mm in length, clear and colorless with brilliantly reflecting faces. The strong twinning tendency gives rise to numerous striations and vicinal planes causing in every case a series of double images from the faces in the prismatic zone. The twinning is complex, in most cases combining the albite and pericline laws. A very common habit of albite twin is shown in figures 13a–13b, the faces illustrated being determined by approximate measurements, as no definite angle values could be obtained by reason of the complex twinning developed. Crystals of this habit occur notably associated with calcite of the crystal combination shown in figure 10b–10c. They are directly implanted on large hornblende masses of the first generation. A twinning habit shown in figure 14a–14b is found on the same specimen in small individuals buried in a mat of white fibrous amphibole which represents an advanced stage of the change from hornblende to byssolite. These rarely exceed 2 mm in length along the brachi axis and are detached and completely developed on all sides. They are milky white in color and penetrated with many inclusions of asbestic amphibole. In twinning they resemble the crystals from Roc Tourné, Savoy.[1] Both types of crystals show surfaces broken by numerous etch pits which correspond in symmetry with the twinning habit. The forms noted are *b* (010), *c* (001), *m* (110), *M* $(1\bar{1}0)$, *f* (130), *z* $(1\bar{3}0)$ *x* $(\bar{1}01)$, *y* $(\bar{2}01)$, *n* $(0\bar{2}1)$, *p* $(\bar{1}11)$, and *o* $(\bar{1}\bar{1}1)$. Two doubtful negative quarter pyramids *q* $(\bar{3}52)$ and *r* $(\bar{4}63)$ in the zone $[\bar{1}11.\bar{1}30]$ were noted as narrow faces but could not be substantiated from the material available. The planes of the hemiprisms (130) and $(1\bar{3}0)$ are developed to an unusual habit for the species while those of the commoner hemiprisms (110) and $(1\bar{1}0)$ are comparatively narrow though well defined. The reading on the measured angles in every instance varied materially from the theoretical value by a variable difference amounting in some instances to 30′ and due to the vicinal twinning according to the Pericline law.

Pyroxene

Pyroxene occurs as the variety augite in dark green to black crystals of prismatic habit associated with orthoclase and amphi-

[1] Rose, G. Poggendorff's Annalen. 1865. p. 125, 457.

bole (hornblende) and always in close association with magnetite. Several crystals were obtained which measured 5 to 15 mm in diameter on the basal axes and 10 to 25 mm in vertical length. These were of a decided prismatic habit, elongated parallel to the *c* axis and showed, in the prismatic zone, a considerable development of the planes of the unit prism. The ortho, clino and basal pinacoids are present, the two former as narrow planes of medium brilliancy and the latter as a series of broad but dull and rough faces. The clinodome *e* (011) is also represented by a series of rough faces, from which, however, fair readings were obtained by using the method of a cemented cover glass. Well developed planes of the positive hemipyramid *i* ($\bar{2}11$) were noted on two of the largest crystals. Figures 15a–15b show a combination of this habit.

Natural etch figures were noted in the prismatic zone on prismatic and pinacoidal faces. Their arrangement, shape and relations to adjacent edges are shown in figure 16. On the planes of the clinopinacoid, these etch figures for the most part take the form of elongated rhombs, the long edges of which are parallel to the edges of the zone and the short edges of which are inclined toward the intersection 010: 011 making the acute angles of the rhombs 46°. In several instances a larger and shallower etch pit was noted on these planes having its sides parallel to the pinacoidal edges. Deep natural etchings occur on the faces of the orthopinacoid, the etch pits in general conforming to the symmetry required by the system. Two types of unsymmetric etch pits shown at b and c on the middle section of figure 16 are apparent exceptions to this general rule; it will, however, be readily seen that a combination of these two outlines produces a symmetric figure of the outline shown at a. Two types of etch pits occurring on the planes of the unit prism are shown at d and e. Both of these types are triangular in shape and are oriented with the long edges at an angle of about 8° with the zonal edges, as shown in the figure. The curved edges in both instances point away from the orthopinacoid and of the remaining straight edges those of type d lie parallel to the intersection 110: 001 and those of type e point toward the negative quadrants, the angles with the zonal edges being as indicated in figure 16. The etch figures show a marked tendency toward arrangement in lines along these latter edges, in the case of d these lines lying parallel to the plane of parting which may be assumed to have a direct influence on the shape of the triangles of type d.

The specific gravity agrees closely with that of augite giving for an average of several determinations on different crystals, G=3.331.

The extinction angle, as determined on a section cut parallel of 010 gave *c* **C**=54°. Thin sections show marked pleochroism as follows:

c = olive-green, **b** = greenish yellow, ***a*** = bluish green.

Amphibole

Amphibole which is by far the most prominent mineral associated with the magnetite of Lyon Mountain, occurs in two varieties. Of these, a black hornblende occurring in immense crystals represents a phase of the same generation as the first generation of quartz previously described. The crystals of hornblende, which show the effects of partial resolution, are more or less corroded exhibiting rough and etched surfaces particularly on planes of the clinodomes. In some instances dendritic deposits of secondary stilbite were noted on the planes of the prismatic zone, a characteristic example of which is shown in plate 9. The following forms were observed: *b* (010), *m* (110), *e* (130), *t* (101), *p* ($\bar{1}01$), *r* (011), *i* (031) and *z* ($\bar{1}21$). The habit is shown in figures 17a-17b. The reflections obtained from the faces were in most instances poor but the values of the measured angles corresponded with theory to a sufficient extent to admit of the identification of forms of such ordinary occurrence.

SUMMARY OF MEASURED AND CALCULATED ANGLES

Angle	Measured		Calculated		Angle	Measured		Calculated	
	°	′	°	′		°	′	°	′
b:e	32	20	32	11	*m′:z*	68	46	69	29
b:m	62	7½	62	5	*m′:r*	96	17	96	10½
b:r	74	15	74	14	*z:z′*	58	50	59	9½
b:i	50	19	49	44	*p:r*	34	22	34	25
					p:t	55	0	55	4

Cleavage parallel to *m* is highly perfect, producing cleavage faces of remarkable brilliancy. The specific gravity is quite high

($G = 3.37$) indicating a clearly marked hornblende. The extinction angle observed on a section cut parallel to 010 gave $c \wedge \mathbf{C}$ 30° 15′. Thin sections are highly pleochroic; $\mathfrak{a}$ = yellowish green, $\mathbf{C}$ = greenish blue.

Thin sections of the wall rock show the derivation of hornblende from the augite previously described, the former mineral therefore taking rank as a secondary derivative. A subsequent change corresponding in generation to the calcite crystals of types III, IV and V has produced from the black hornblende a light green byssolite which in its advanced stages of metamorphism is reduced to a whitish, asbestic amphibole. A striking example of this first change is shown in the specimen depicted in plate 10 where the black hornblende is seen to terminate in feathery brushes of byssolite which latter mineral is accompanied by secondary albite derived from the primary orthoclase. The byssolite, in its color, properties and association resembles that from Knappenwand in the Tyrol. As near as could be determined the extinction angle measures $c \wedge \mathbf{C} = 15°$.

Zircon

Zircon is found in pegmatite in close proximity to the iron ore at the Parkhurst shaft, 1½ miles east of the main workings at Lyon Mountain. The crystals which occur embedded in orthoclase and quartz range in size from 8 to .5 mm in diameter, the larger individuals invariably occurring in orthoclase. They are lilac-brown in color and vary in translucency from opaque in the larger specimens to translucent in the smaller ones, many of which show reddish by transmitted light. Many of the crystals show grayish zones symmetrically disposed on the terminations as indicated in figure 18b. The faces in the prismatic zone are sharp and brilliant and gave excellent reflections. In the zone [110.111] the planes of *u* and *v* are narrow and ill defined but, however, yield fair reflections and were established beyond question. The ditetragonal pyramid *x* (311) occurs only on the smaller crystals shown in figures 19a–19b, which were found embedded in quartz. In general these latter crystals were more brilliant and perfectly formed and yielded better reflections than the larger types represented in figures 18a–18b.

The results obtained from the measurements of eight of the best crystals are given below:

	Angle	Measured °	Measured ′	Calculated °	Calculated ′		Angle	Measured °	Measured ′	Calculated °	Calculated ′
m:a	110:110	45	1	45	0	*p:p‴*	111:1$\bar{1}$1	56	42	56	40
m:m′	110:$\bar{1}$10	90	1	90	0	*u:u‴*	331:3$\bar{3}$1	76	13	76	29
m:u	110:331	20	16	20	12½	*a:x*	110:311	31	50	31	43
m:v	110:221	29	5	28	54	*a:p*	110:111	61	38½	61	40
m:p	110:111	47	43	47	50	*x:x^v‴*	311:3$\bar{1}$1	32	45	32	57
p:p″	111:$\bar{1}\bar{1}$1	84	25	84	20						
u:u″	331:$\bar{3}\bar{3}$1	139	35	140	35						
v:v″	221:221	122	57	122	12						

Epidote

Epidote occurs in irregular strings scattered through the orthoclase of the pegmatitic phase of the wall rock and usually in close association with light gray massive wernerite. In several instances phenocrysts of amphibole in a wernerite matrix were noted which showed a distinct rim of epidote indicating a probable derivation of the latter mineral from a previously deposited amphibole. Measurable crystals were obtained from small veins, where they occurred deposited on a thin layer of bluish green marmolite and partially imbedded in massive calcite which constituted the ultimate vein filling. These crystals which average 3 mm in length show no unusual development in crystal forms or habit. Figures 20a–20b show this habit, to which all the crystals studied conformed with great regularity. The planes of the zone [100.001] are sharp and brilliant although frequently marred by vicinal striations. In many instances the crystals are somewhat bent. The planes of the hemipyramid *n* ($\bar{1}$11) are rough and dull while those of the prism *u* (210) although extremely small are well marked and bright. The following forms were noted: *a* (100), *c* (001), *u* (210), *e* (101), *r* ($\bar{1}$01) and *n* ($\bar{1}$11).

	Angle	Measured °	Measured ′	Calculated °	Calculated ′		Angle	Measured °	Measured ′	Calculated °	Calculated ′
c:a	001:100	64	34	64	37	*a:e*	100:101	29	45	29	54
c:r	001:$\bar{1}$01	63	34	63	42	*n:n‴*	$\bar{1}$11:11$\bar{1}$	70	26	70	29
a:r	100:$\bar{1}$01	52	11	51	41	*u:u′*	210:2$\bar{1}$0	109	7	109	1

Stilbite

Stilbite occurs abundantly in drusy crusts and aggregates of colorless transparent crystals and in yellow to brown sheafs, all of which display the characteristic pearly luster on the clinopinacoid. The planes of *m* (110), usual in the twinned parallel grouping of stilbite, are here replaced by those of the hemiorthodome *f* ($\bar{1}01$) which with the pinacoidal planes *c* (001) and *b* (010) produce a combination varying but slightly in shape from a right parallelopiped, and which give to the parallel groupings a flat rather than a serrated aspect. This parallel grouping is shown in figure 21. The usual penetration twins with the twinning plane parallel to *c* are apparent in sections parallel to *b* in polarized light.

Biotite

Biotite in distinct crystals occurs imbedded in calcite of type I from a vug opening into the 600-foot level. The crystals average 20 mm in diameter and show fair development of the planes of μ ($\bar{1}11$) and *b* (010). A marked twinning habit with *c* for the composition face was noted in a number of instances, the arrangement of the crystals being that shown in figure 22. No accurate readings could be obtained in the reflection goniometer owing to the dull and irregular character of the faces, but sufficiently close measurements were reached with the contact goniometer to identify the forms *b* (010) and μ ($\bar{1}11$). A decided tapering toward the vertical termination due to "stepped" crystals in parallel position is characteristic of the occurrence. The crystals are black in color and only transparent in very thin plates. The interference figure in convergent light shows a small axial angle.

Titanite

Titanite of the variety lederite was obtained from the walls of the largest "vug" opening into the 600-foot level. The crystals which measured 3 to 15 mm on the *b* axis occur associated with orthoclase, magnetite and quartz of the first generation. They are dark brown to black in color and show brownish red in thin sections by transmitted light. A distinct parting parallel to η (221) gave a measured angle of 125° 35′ corresponding to a calculated value $\eta \wedge \eta'$ 125° 42′. The prevailing crystal habit is shown in figures 23a–23b, although in one instance a considerable development of the planes of *n* (111) produced an elongation parallel to these planes which simulated a prismatic habit. The observed planes lie mostly

in the zone [001.110] and are, for the most part, brilliant and sharply defined. Vicinal developments which were noted throughout this zone are probably due to the rounding of the edges characteristic of this variety. Twinning parallel to *a* is common to this occurrence, the twinning habit producing sharply defined reentrant angles between *c* and $\bar{c}$. The forms observed with their measured and calculated angles are given below:

SUMMARY OF MEASURED AND CALCULATED ANGLES

Form		Angle		Measured		Calculated	
				°	′	°	′
c	001						
a	110						
b	010						
m	110	*c:m*	001:110	65	16	65	30
		m:m‴	110:$1\bar{1}0$	66	17	66	29
		b:m	010:110	56	46	56	46
n	111	*c:n*	001:111	38	4	38	16
		n:n′	111:$1\bar{1}1$	43	25	43	49
η	221	*c:η*	001:221	49	7	49	15
		η:η′	221:$2\bar{2}1$	54	25	54	18
t	$\bar{1}11$	*c′:t*	$00\bar{1}$:$11\bar{1}$	70	17½	70	23
		t:t′	$\bar{1}11$:$\bar{1}\bar{1}1$	68	53	69	9
l	$\bar{1}12$	*c′:l*	$00\bar{1}$:$11\bar{2}$	40	25½	40	34

Apatite

Apatite occurs quite abundantly both as a primary mineral associated with orthoclase and hornblende in large crystallizations, and as a secondary mineral, deposited from resolution of the former phase in small crystals associated with the calcite of types III, IV and V. Both phases of apatite give distinct reactions for chlorine and fluorine. The crystals of the first generation were obtained from the vug opening into the 600-foot level which furnished the large hornblende crystals previously described. Like these, the crystals of apatite are in many instances of unusual size, the one shown in plate 11 measuring 7 cm in diameter while many of those lining the walls of the vug were considerably larger. They show marked indications of an aqueo-igneous origin and were undoubtedly subjected to considerable mechanical stress when still in a plastic condition. A striking evidence of this latter fact is given by the specimen shown in plate 11. In this instance heart-shaped

wedges of orthoclase have been driven into the perfectly formed apatite crystal causing a distinct inward curve of the surface around the edges of the puncture and a decided bulging of the material displaced by the injected wedge. The writer has produced a similar aspect in a prism of softened paraffin by gently pressing into its surface a steel wedge. The surfaces of the crystals show natural etchings corresponding in symmetry with the hexagonal pyramidal group. In general the apatite crystals of this phase resemble those from Natural Bridge and other localities in northern New York. The crystal faces do not admit of accurate measurements by reason of the rounded and uneven character of the surfaces. The forms *m* ($10\bar{1}0$), *x* ($10\bar{1}1$) and *s* ($11\bar{2}1$) were identified with a contact goniometer.

Secondary apatite occurs in small bright crystals, perfectly transparent and light yellowish green to bluish green in color. The largest of these measured 6 mm in diameter. They show an apparent rounding at the termination which renders the determination of the crystal habit a matter of some difficulty. Fair reflections of the goniometer signal were obtained in all zones measured and the forms recorded were noted on all of the three crystals studied. The crystal habit as determined by the relative size of the reflecting surfaces is shown in figures 24a–24b. The following summary shows the results obtained from the measurement of three of the best developed of these crystals.

SUMMARY OF OCCURRING FORMS, MEASURED AND CALCULATED ANGLES

	Form	Angle	Measured		Calculated	
			°	′	°	′
c	0001	$10\bar{1}0:0001$	90	2½	90	0
m	$10\bar{1}0$	$10\bar{1}0:01\bar{1}0$	60	0	60	0
a	$11\bar{2}0$	$10\bar{1}0:11\bar{2}0$	30	0	30	0
r	$10\bar{1}2$	$10\bar{1}0:10\bar{1}2$	67	12	67	1
x	$10\bar{1}1$	$10\bar{1}0:10\bar{1}1$	49	42	49	42
		$10\bar{1}0:01\bar{1}1$	71	8½	71	8
		$01\bar{1}1:\bar{1}101$	37	43	37	44½
y	$20\bar{2}1$	$10\bar{1}0:20\bar{2}1$	30	38	30	31
w	$70\bar{7}3$	$10\bar{1}0:70\bar{7}3$	26	40½	26	48
z	$30\bar{3}1$	$10\bar{1}0:30\bar{3}1$	21	25⅓	21	27
s	$11\bar{2}1$	$11\bar{2}0:11\bar{2}1$	34	17½	34	14½
		$10\bar{1}0:11\bar{2}1$	44	18½	44	17
μ	$21\bar{3}1$	$10\bar{1}0:21\bar{3}1$	30	19⅔	30	20

GENERAL CONCLUSIONS

The occurrence at Lyon Mountain of two distinct phases of a mineral species, as has been noted in the cases of quartz, calcite, the feldspars, amphibole and apatite, points unquestionably to two distinct periods of mineral deposition. Of these, the first may be said to be characterized by the production of large crystallizations from an aqueo-igneous fusion, of which the superheated water acted as a powerful solvent. The marked prevalence of natural etched pits on the surface of the minerals of this phase, as well as their partial resolution bears evidence of the potency of this dissolving action. Considerable mechanical stress accompanied the formation of the minerals of this period and the evidence is not lacking that the perfectly formed minerals were still in a soft or pasty condition when subjected to external pressure.

The second stage of mineral production, which is marked by smaller and more perfectly crystallized individuals, was the result of recrystallization of the dissolved materials from the saturated aqueous solution, the dissolving action of which is apparent in the minerals of the first period. In some instances this second period may have been contemporary with the first, as in the case of the calcite of type I. In general, the minerals of secondary derivation are to be found incrusting those of the previous generation indicating a complete change in the mode of production.

Plate I

EXPLANATION OF PLATES

1a Pyrite from Lyon Mountain. Orthographic projection showing forms: a (100), o (111), e (210), S (321) and n (211)

1b Clinographic projection of same

2a Quartz from Lyon Mountain. Orthographic projection showing forms: m $(10\bar{1}0)$, r $(10\bar{1}1)$, $\Gamma(40\bar{4}1)$, z $(01\bar{1}1)$, s $(11\bar{2}1)$, x $(51\bar{6}1)$ and q' $(10.1.\overline{11}.1)$

2b Clinographic projection of same

3a Hematite from Lyon Mountain. Orthographic projection showing forms: c (0001), r $(10\bar{1}1)$ and n $(22\bar{4}3)$

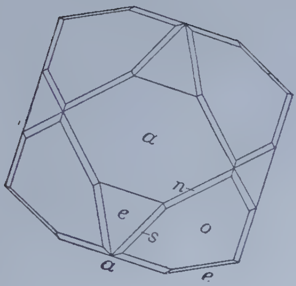
3b Clinographic projection of same

4a Calcite from Lyon Mountain, type I. Orthographic projection showing forms: M $(40\bar{4}1)$ and μ $(54\bar{9}1)$

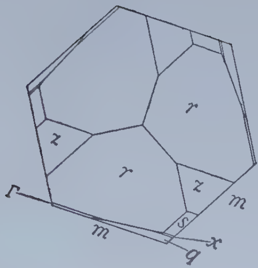
4b Clinographic projection of same

Plate I

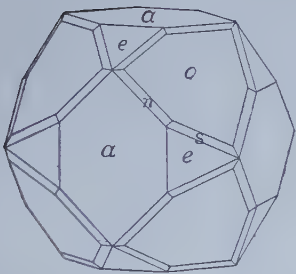
1a



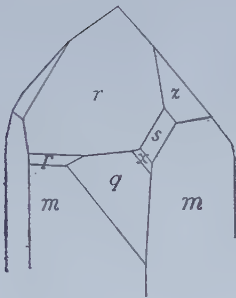
2a



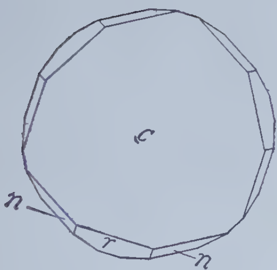
1b



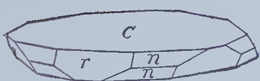
2b



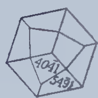
3a



3b



4a



4b

Plate 2

5a Calcite from Lyon Mountain, type I. Orthographic projection showing forms: M $(40\bar{4}1)$, E $(0.13.\overline{13}.4)$ and μ $(54\bar{9}1)$

5b Clinographic projection of same

6a Calcite from Lyon Mountain, type II. Orthographic projection showing forms: Υ $(0.19.\overline{19}.13)$ and **q**: $(24\bar{6}1)$

6b Clinographic projection of same showing parallel grooving caused by the vicinal development of the forms c (0001) and e $(01\bar{1}2)$

7a Calcite from Lyon Mountain, type III representing the simplest expression of the pyramidal habit. Orthographic projection showing forms: Γ $(22\bar{4}3)$, γ $(8.8.\overline{16}.3)$ and Υ $(0.19.\overline{19}.13)$

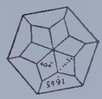
7b Clinographic projection of same

8a Calcite from Lyon Mountain, type III. Orthographic projection showing forms: Γ (2243), γ $(8.8.\overline{16}.3)$, l $(04\bar{4}5)$ Υ $(0.19.\overline{19}.13)$, v $(21\bar{3}1)$ and $\mathfrak{U}$: $(14.12.26.5)$

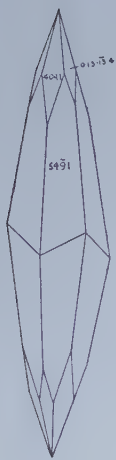
8b Clinographic projection of same

Plate 2

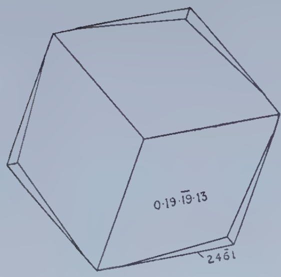
5a



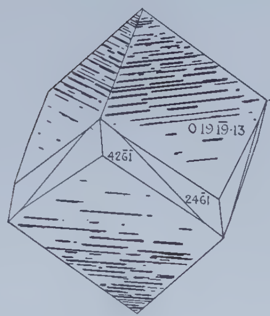
5b



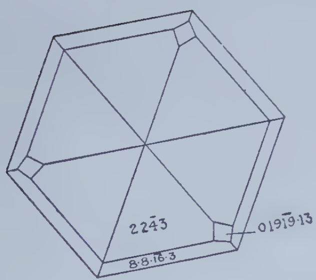
6a



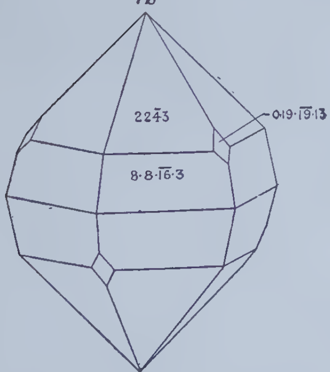
6b



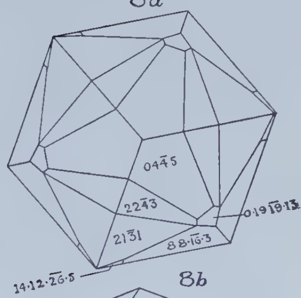
7a



7b



8a



8b

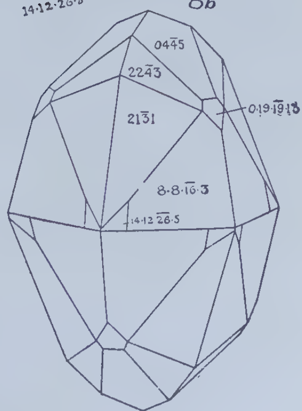


Plate 3

9a Calcite from Lyon Mountain, type IV, rhombohedral habit with pyramidal modifications. Orthographic projection showing forms: Γ $(22\bar{4}3)$, γ $(8.8.\overline{16}.3)$, A $(04\bar{4}3)$ and v $(21\bar{3}1)$

9b Clinographic projection of same

10a Calcite from Lyon Mountain, type IV. Clinographic projection showing an element of the compound crystal figured in 10b–10c. Forms: π $(11\bar{2}3)$, Γ $(22\bar{4}3)$, γ $(8.8.\overline{16}.3)$, A $(04\bar{4}3)$, v $(21\bar{3}1)$, μ $(54\bar{9}1)$, $\mathfrak{U}$: $(14.12.\overline{26}.5)$ and $\mathfrak{q}$: $(24\bar{6}1)$

10b Calcite from Lyon Mountain, type IV. Orthographic projection showing a compound crystal consisting of the elements shown in 10a symmetrically disposed in parallel position on a rhombohedron r $(10\bar{1}1)$ of a previous generation

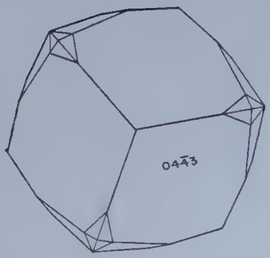
10c Clinographic projection of same

11a Calcite from Lyon Mountain, type V. Orthographic projection showing forms: Γ $(22\bar{4}3)$, $\propto$ $(44\bar{8}3)$, l $(04\bar{4}5)$ A $(04\bar{4}3)$, f $(02\bar{2}1)$, Δ. $(07\bar{7}2)$, Σ. $(0.11.\overline{11}.1)$, v $(21\bar{3}1)$, $\mathfrak{R}$: $(8.4.\overline{12}.1)$, $\mathfrak{q}$: $(24\bar{6}1)$ and c: $(34\bar{7}1)$

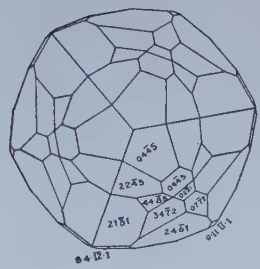
11b Clinographic projection of same

Plate 3

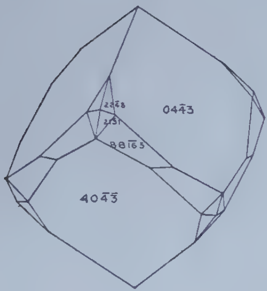
9a



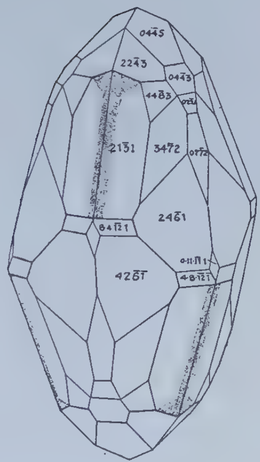
11a



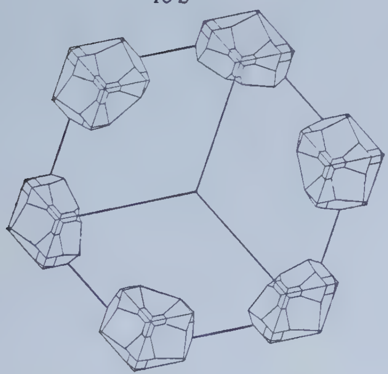
9b



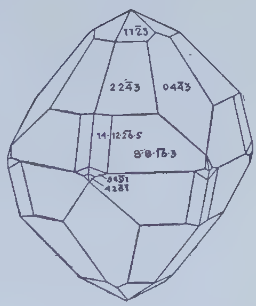
11b



10b



10a



10c

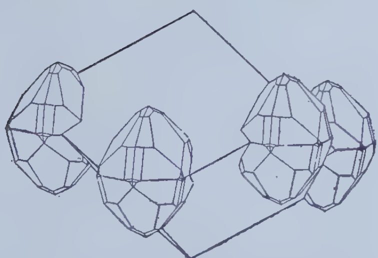
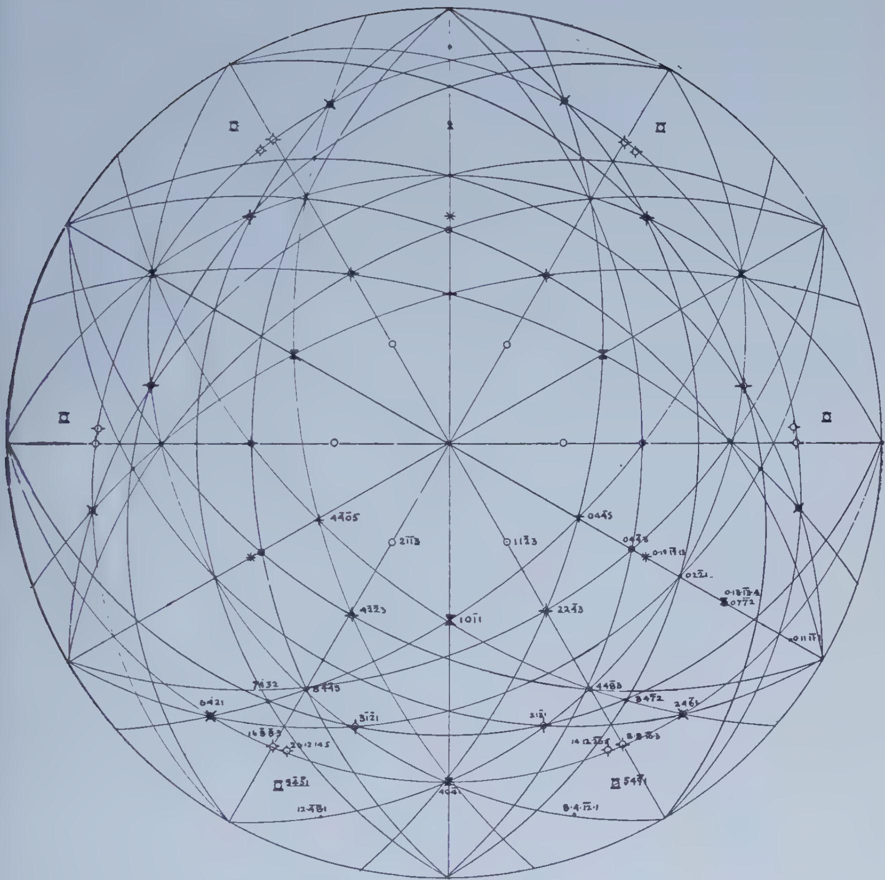


Plate 4

12 Calcite from Lyon Mountain. Stereographic projection showing distribution and zonal relations of the forms occurring on the five types

Plate 4

12



Forms of Type I ⧗
" " II ×
" " III +
" " IV ○
" " V ✔

Plate 5

13a Albite from Lyon Mountain. Orthographic projection showing prevailing type of twin according to the albite law. Forms: *b* (010), *c* (001), *m* (110), *M* ($1\bar{1}0$), *f* (130), *Z* ($1\bar{3}0$), *x* ($\bar{1}01$), *y* ($\bar{2}01$), *p* ($\bar{1}11$) and *o* ($\bar{1}\bar{1}1$)

13b Clinographic projection of same

14a Albite from Lyon Mountain. Orthographic projection of cross penetration twins according to the albite law

14b Clinographic projection of same

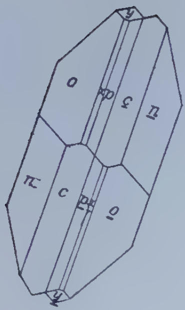
15a Pyroxene from Lyon Mountain. Orthographic projection showing forms: *a* (100), *b* (010), *c* (001), *m* (110), *e* (011) and *i* ($\bar{2}11$)

15b Clinographic projection of same

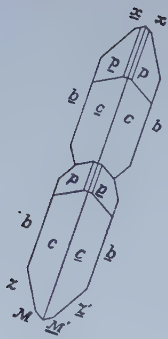
16 Development of planes in the prismatic zone of 15b showing shape and distribution of natural etch pits and their relation to adjacent edges

Plate 5

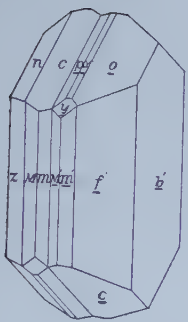
13a



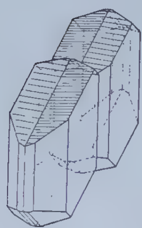
14a



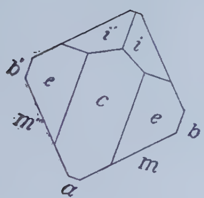
13b



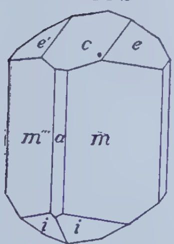
14b



15a



15b



16

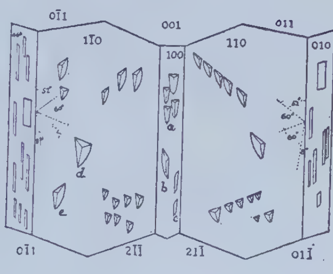


Plate 6

17a Amphibole from Lyon Mountain. Orthographic projection showing forms: *b* (010), *m* (110), *e* (130), *t* (101), *b* (101), *r* (011), *i* (031) and *z* $(\bar{1}21)$

17b Clinographic projection of same

18a Zircon from Parkhurst shaft, Lyon Mountain. Orthographic projection of type of larger crystals. Forms: *m* (110), *a* (100), *p* (111), *v* (221) and *u* (331)

18b Clinographic projection of same

19a Zircon from Parkhurst shaft, Lyon Mountain. Orthographic projection of type of smaller crystals. Forms: *m* (110), *a* (100), *p* (111) and *x* (311)

19b Clinographic projection of same

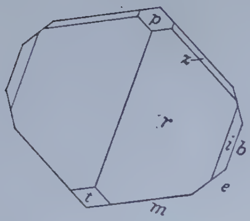
20a Epidote from Lyon Mountain. Orthographic projection on a plane parallel to *b* (010), showing forms: *a* (100), *c* (001), *u* (210), *e* (101), *r* $(\bar{1}01)$ and *n* (111)

20b Clinographic projection of same

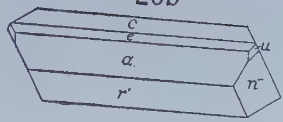
21 Stilbite from Lyon Mountain. Clinographic projection showing parallel grouping. Forms: *c* (001), *b* (010) and *f* (101)

Plate 6

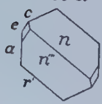
17*a*



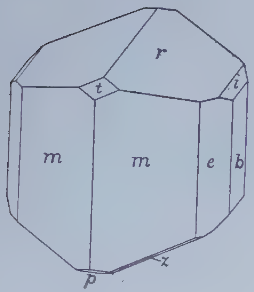
20*b*



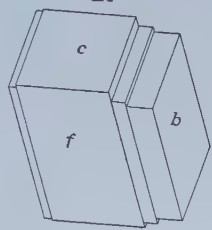
20*a*



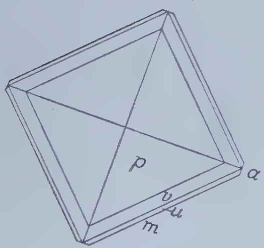
17*b*



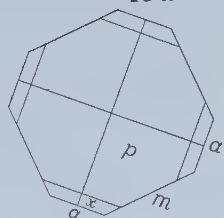
21



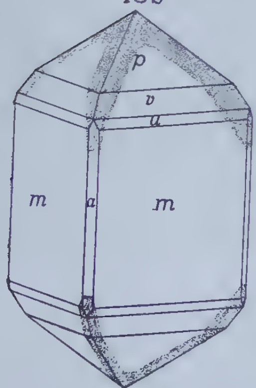
18*a*



19*a*



18b



19b

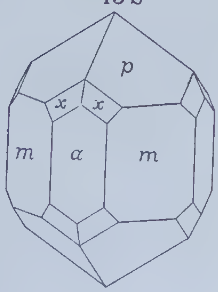


Plate 7

22a–22b Biotite from Lyon Mountain. Clinographic projections showing types of twins. Forms: *c* (001), *b* (010) and μ ($\bar{1}11$)

23a Titanite from Lyon Mountain. Orthographic projection showing forms: *c* (001), *a* (110), *b* (010), *m* (110), *n* (111), η (221), *t* ($\bar{1}11$), and *l* ($\bar{1}12$)

23b Clinographic projection of same

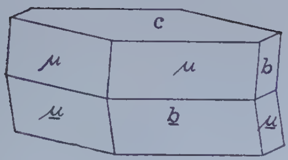
23c Clinographic projection on a plane at right angles to that shown in 23b and showing a crystal of the same habit twinned parallel to *a*

24a Apatite from Lyon Mountain. Orthographic projection showing type of crystal of secondary derivation. Forms: *c* (0001), *m* ($10\bar{1}0$), *a* ($11\bar{2}0$), *r* ($10\bar{1}2$), *x* ($10\bar{1}1$), *y* ($20\bar{2}1$), *w* ($70\bar{7}3$), *z* ($30\bar{3}1$), *s* ($11\bar{2}1$) and μ ($21\bar{3}1$)

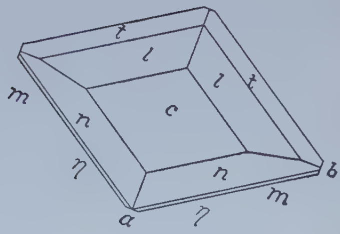
24b Clinographic projection of same

Plate 7

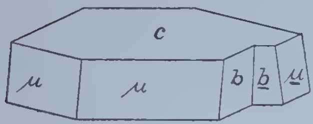
22 a



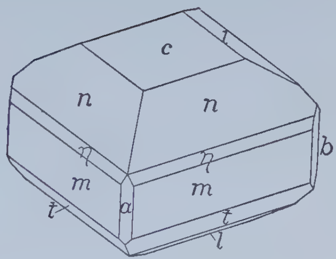
23 a



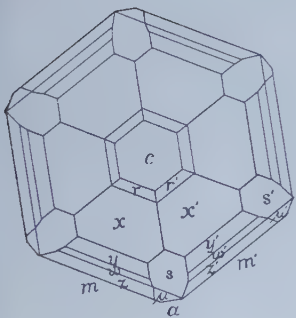
22 b



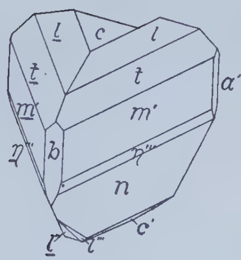
23 b



24 a



23 c



24 b

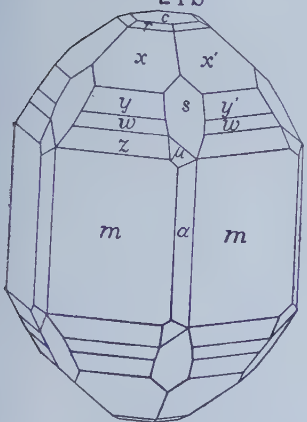


Plate 8

Secondary quartz from Lyon Mountain showing occurrence of secondary hematite in shotlike hemispheres and circular disks. The scale is divided into centimeters.

Plate 8

Plate 9

Amphibole (hornblende) from Lyon Mountain showing dendritic deposit of stilbite on planes in the prismatic zone. The specimen is reproduced in natural size.

Plate 9

Plate 10

Amphibole and quartz from Lyon Mountain showing transition stage from hornblende of the first generation to byssolite of the second and also the crust of secondary albite and stilbite on the primary minerals. The scale is divided into centimeters.

Plate 10

Plate II

Crystals of apatite of the first generation in pegmatite, from Lyon Mountain, showing a wedge of orthoclase driven into the side of the crystals by external force. The orthoclase fragment appears as a heart-shaped spot near the upper edge of the specimen. Note the bulging of the edge of the crystal around the fragment. The scale is divided into centimeters.

Plate 11

ON SOME PELMATOZOA FROM THE CHAZY LIMESTONE OF NEW YORK

BY

GEORGE HENRY HUDSON

In some material from Valcour island, Lake Champlain, given by me to Mr Percy E. Raymond in 1902 he was so fortunate as to find a fragment of Blastidocrinus carchariaedens Bill. with two of the large deltoid interambulacral plates in position and showing much of the internal structure of an ambulacrum [pl. 5 fig. j]. In 1903, while examining some excavated material from the same locality (which the writer had left out to weather), Dr C. E. Beecher found a small fragment of a crushed individual which showed a pair of the plates I have called bibrachials, nearly in their proper relation to the great deltoids. In 1904 the writer found two bibrachials joined along their common suture, and these are figured on plate 4 at L. While gathering up some of the remaining portions of the same weathered stratum in 1905, Erastus M. Hudson obtained the most complete specimen of this species yet found. From this material and from about a thousand separate plates kindly assembled for me by Miss Ada M. Carpenter from the unassorted collections of some years, and representing over 186 different individuals, as shown by that number of apical pieces, I have made the following more complete description of this interesting species.

Blastoidocrinus carchariaedens Billings

Can. Org. Rem. Decade IV. 1859. p. 18, pl. 1, fig. 1a-1s

Plates 1–7, text figures 1–3

General description. Theca large, in some specimens attaining a hight of 36 mm and a width of more than 40 mm, pentagonal, clearly separated into an oral and aboral surface with the greatest width at the boundary.

Aboral portion of theca deeply invaginated, appearing in a side view as a low, inverted, truncate cone whose outer walls

make an angle of 58° with the vertical; the ratio of the length of these outer walls to the distance across the invaginated area in a specimen a little more than half grown is as 11 to 9, in older specimens the difference is greater.

The oral portion, when the high ambulacral ridges and anal piece are in position, is four times as high as the aboral and rises from it as a dome, maintaining a vertical outline for nearly one third its hight.

The published restorations of this species have been made from fragments showing but very little of the aboral portion and with the ambulacral ridges and anal piece broken from the oral surface. These figures give the aboral portion nearly twice the hight of the oral while in reality the oral has very nearly four times the hight of the aboral. A side view of this species seems therefore to be more strongly suggestive of Pentremites than Mr Billings supposed.

The plates of the aboral surface, while nearly 80 in number, are arranged in four horizontal circlets. The first two are of basals and radials as in crinoids. The plates of the third circlet consist of 10 bibrachials and 13 interbrachials. The plates of the fourth circlet are between 50 and 60 in number but while the alinement is horizontal and not zigzag, the circlet is cut at each radius by the upward extension of the bibrachials.

The radials are so remarkably like the basals of certain Rhodocrinidae and are so abundant in Chazy deposits that it has seemed best to describe them rather more fully than is usual.

Basals. Basals unknown but probably very small and together having but little greater area than a joint of the stem. The "basals" of E. Billings, of which he says "from another specimen it appears that there are at least three, if not four or five, basal plates, and their form is remarkable," are not basals but radials. All published statements concerning the basals have been made on the authority of the quoted passage and are without value.

Radials. Radials five, many angled; each having two (?) proximal very short sides resting against the basals; two long sides where each plate meets its neighbor in this circlet; next above this on the left is a side which supports the largest plate of a lower row of two or three interbrachials; on the right are either two or three sides meeting the whole lower row of interbrachials; the remaining two sides, which are distal, support the bibrachials.

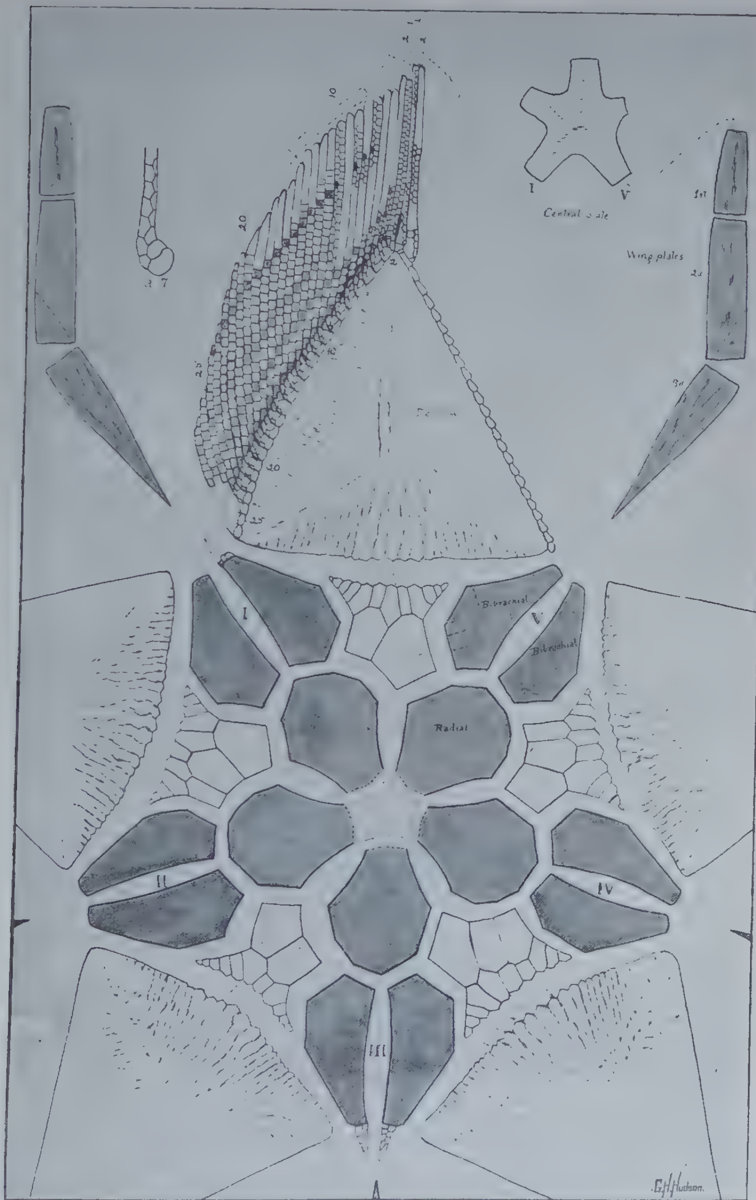


Fig. 1 Analysis of the theca of Blastoidocrinus carchariaedens. The brachioles have been drawn for one side of one of the deltoids and all their external ossicles outlined save a portion of those between the 1st and the 10th and the tips of the 11th to the 18th. The 6th external ossicles have been shaded as have also the 10th, 14th and 22d ossicles of the uniserial brachioles. At a7 the lower ossicles of the 7th brachiole have been drawn to a larger scale. The wing plates of but two of the radii are shown. The piece marked "central plate" is the apical piece.

The radials are thus seen to be unsymmetrical, supporting one or two more plates on their right sides than on their left. This has turned the apex of each plate to the left and through the bibrachials has moved the distal or outer end of each ambulacrum from 7 to 10 degrees from its expected position, as is shown in plate 1, lower figure. The center of this figure was found by extending inwardly the lines marking the suture between each pair of radials. The position of these lines extended outwardly is marked on the circle nearly surrounding the figure.

The proximal portions of the radials are gradually bent upward [pl. 4. k] to form an angle of 90 degrees with a line across the base of the theca. They thus together form a deep conical pit or crater whose outer rim is a little more than twice the diameter of the stem but which gradually becomes narrower as it penetrates the theca and brings the thin, inner portions of the plates against the stem at a depth of seven or more of the stem rings. The outer or distal portion of the radials is bent upward at an angle of 30 degrees with the line across the edge of the crater and this portion of the plate (one third or less of its length) is from 1 to 2 mm in thickness at the suture or from three to six times the thickness of the edge next the basals. An exception to this thickness is made where the radial meets the smallest interbrachial plate of the lower row; here the thickness at the edge is markedly reduced, as shown in plate 4 at i.

Each plate shows a raised central mound on the rim of the crater, carrying this rim outward a little and giving it a somewhat pentagonal figure. From this mound, or just above it, there radiate some 10 or 20 depressed grooves, the more nearly transverse ones being the deeper and together making a marked transverse depression a little below the apex of each plate. The more marked of these lines run across the suture and either across or between the lower line of interradials. The portion of the plate forming the inside of the crater is ornamented by some fine rounded labyrinthine ridges as in plate 4, g, or a dewdrop pattern as at h. The inside surface of these plates is smooth with sometimes a raised central, longitudinal ridge at the bend; probably representing attachment of viscera [pl. 4, i and j]. The largest radial so far found measures 10.48 mm across at greatest diameter or very nearly twice the diameter of the radials of the specimen figured in plates 1, 2 and 3. This plate [pl. 4, a] shows less ornamentation than the others but the radials seem to vary rather markedly in this respect. Fig-

ure c on the same plate shows rather clearly a series of growth lines, or rather rest lines, where periodic pauses seem to have been made in addition to the edge of the plate.

The resemblance of these plates to the basals of certain Rhodocrinidae (especially to those genera with concave bases and two or more interradial plates over the no longer truncate upper edge of the radial) lies in their approximate size, the bent condition, the thinner proximal portion, the radiating ridges on the distal surface, the depressed apex, the occasional visceral ridge [*see* text fig. 8] and the more than usual number of angles. In the Rhodocrinidae, however, the distal ornamented area is usually much greater than the bent proximal area. The plates once recognized are easily separated from all others.

Bibrachials. In each radius of the third circlet is a pair of usually hexagonal plates each about one and one third times as long as the greater width of the radials and a little less than half as wide as they are long. The bibrachials meet over the apex of a radial in one long, straight suture and their narrow (sometimes rather pointed) distal ends reach the boundary of the oral surface and together support the end plates of an ambulacrum and usually four very short brachioles. The outer edge of each plate has three sides; the two lower meet the end plates of the two rows of interbrachials and the remaining side meets the horizontal outer third of the base of one of the great deltoids and thus also reaches the oral boundary.

The outside of the plate is ornamented with transverse, fold-like, rather rough ridges which become less prominent and disappear as they reach the long common suture of the two plates. The inside surface is smooth. The face of the common suture is very smooth and near the middle of the plate this suture occupies half its width, the plates together making a very strong element of the theca. The outer suture is crossed by numerous grooves which, at least on the upper half, mark the position of the pores or slits on the deltoid through which water passes from the hydrospires to the exterior. These features may be seen in figures l, m and n, on plate 4. The number of external, transverse ridges and the number of grooves across the outer suture will depend on the age of the plate as we shall see under the description of the deltoids.

These plates have been called *bibrachials* without any intention of signifying that they are homologous with the brachials of crinoids. They support the distal, not the proximal end of

an arm. The first and second circlet of similar forms have however received crinoid terminology and I have used similar terms for the plates of the third and fourth circlets. These last circlets lie in the brachial region of crinoids. The bibrachials here follow the radial as if that were a primaxil and the pair suggest the II Br_1 of crinoids with their long axes placed vertically instead of horizontally. I do not mean to lead the reader to conclude that I have considered these plates as divided radials though a comparison with the higher blastids might hastily lead one to that conclusion. Three other hypotheses suggest themselves which may be here given without comment. These plates may be homologous with the cystidean pair of plates that would very naturally lie over what became a radial (through reduction of number and acquisition of pentamerous symmetry), possess a vertical common suture and become modified on being reached by the extending oral food grooves. That is, these plates may be considered strictly interradial and without radial elements between them. In this case they are but specialized plates similar in origin to the other plates of the third circlet. The double character of these plates and their position at the end of a long double row of highly specialized adambulacrals might lead us to adopt the hypothesis that they were derived from the outermost adambulacrals of such a form as Proteroblastus on which a more distinct differentiation into oral and aboral surfaces had been impressed together with loss of function at the aboral end of the arm. A third hypothesis, and one perhaps more suggestive than the last, would be to look on these bibrachials as true interambulacrals thrust from the oral surface and to their present radial position by the great development of the deltoids but still bearing brachioles and outward markings indicating a former respiratory function.

Interbrachials. In each interradius there are two or three interbrachials of the third circlet, one much larger than the other, and from 10 to 12 smaller plates of the fourth circlet. The upper ends of the latter are each in contact with the middle part of the great deltoid above. They no doubt once functioned as respiratory plates and to a certain extent they may still do so though any such present function is unknown. The arrangement, shape and relative size of these plates is shown in figure 1 of the text as is also their contact with the bibrachials and radials. Plates 2 and 3 show four different groups of these interbrachial plates

in position. These plates complete the aboral surface of the theca.

Deltoids. Perhaps the most remarkable structures of the oral surface are the great deltoids—large triangular plates, each of which has come to occupy an entire interambulacral area. The superficial resemblance of these plates to "sharks' teeth" evidently suggested the specific name, and such plates have induced local collectors to stoutly maintain that "big fish" existed in Chazy time.

These interambulacral plates have the middle basal portion strongly bent inward and the lateral portions rather markedly outward; a vertical section of one such plate would thus be convex outwardly and a transverse section concave outwardly. The two upper or lateral sides of each plate support on each edge from 6 (or less) to 40 (or more) brachioles with their corresponding adambulacral or flooring plates.

Each bordering brachiole (with the possible exception of one of the apical pair) is connected, by a pore or slit *between* the adambulacrals, with a vertical or rather a longitudinal groove on the inner surface of the deltoid. From both sides of this groove there extends a remarkably thin respiratory sheet, slightly bent away from its fellow soon after its origin and usually still more so near its inner margin where the edges meet in a rounded roof and form a lamellar cavity through which was maintained a flow of sea water which made its exit at a short slit at the base of the deltoid. This row of basal slits, one for each hydrospire, is very clearly shown in plate 5 at j. This figure is reduced from a photographic enlargement and as the slits did not appear as dark as in the specimen, the seven outer ones were darkened with india ink; the remaining slits have been reproduced without retouching of any kind. The bibrachial shown in the figure had been moved slightly inward from its natural position and the specimen thus shows the water exits to better advantage. The arrangement of these hydrospires on the plate may be seen in figure 2 which is from a camera lucida drawing of a cróss-section of the right posterolateral interradial deltoid made at, or just below the 17th brachiole and which shows 34 hydrospires.

The most rapid increase of growth of the deltoid was at the two lower angles where new brachioles were regularly added at the side of and just below the last formed, until the number became perhaps as many as 50 on a side, giving a probable total

of 500 brachioles to some old specimens. With each added brachiole there was also added a very short, rudimentary hydrospire consisting at first of a membranous fold open externally. As the hydrospires with their grooves are no farther apart in adult specimens than in young ones [*see* pl. 5 fig. k-o of inner surface of deltoids, where approximately 14 grooves lie side by side in a width of 5 mm whether young or old plates are taken] it follows that direct lateral growth was limited to the widening of the plate by the addition of these new brachioles and their hydrospires.

Direct upward extension of the hydrospire and the portion of the plate bearing it would soon bring the base of any one brachiole up to the level of the former position of its next older companion while the companion constantly maintained its former superior relation by a similar upward extension of its own hydrospire and plate portion. Thus the plate was indirectly widened by upward growth of the portions consecutively added at the lower angles. This upward extension in the early stages of the development of the plate was no doubt as rapid as the extension of the lower angles, but at a later stage the lower angle extension was the more rapid.

The rather remarkable parallelism of the hydrospires would show that the basal plates of a young brachiole ceased to grow as soon as a subsequent brachiole was added. That there was a slight enlargement of the later formed brachioles is however shown in plate 5, figure o, where the grooves of the hydrospire, between 30 and 39, begin to show a very appreciable change in direction. Another fragment not figured shows a still greater extension of this angle of a plate and a change in the direction of the grooves of more than 45 degrees. It is on this bit of evidence that I have suggested that the 39 side grooves of plate 5, figure o, may have been surpassed in this specimen by at least 11 others. Its possessor must have shown a more remarkably starfishlike form, when viewed axially than the specimen figured in plate 1. It must also have brought the ends of its ambulacra more nearly down to a level with its base.

The hydrospires and their plate portions were also extended downward and the points of their origin became thus left along a line still visible on the external surface of the plate and connecting the older central portion with the newer extension of the angles. This line may be seen in plates 1, 2 and 3, and is also clearly shown in plate 5, figure j. This downward exten-

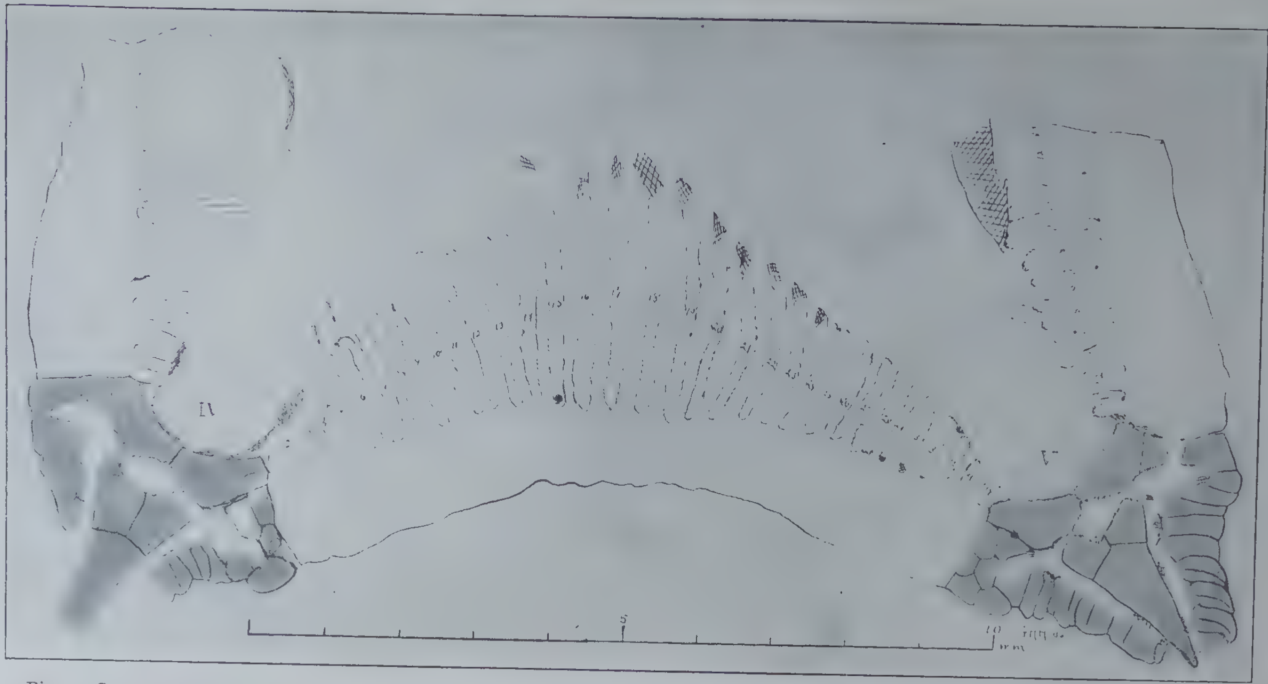


Fig. 2 Camera lucida drawing of a transverse section through a deltoid and two ambulacra of B. carchariaedens. The position of the section is indicated in plate 3. The ambulacral elements are shaded and surround unshaded areas where the section transmitted much light. The cross hatching indicates the position of internal deposits of a very fine yellowish sand or clay, the finer stippling indicates carbonaceous deposits. Four arrows point to detached inner edges of hydrospires. The 15th hydrospire has also lost its inner edge as indicated by the falling in of its load of the yellowish earthy deposit. The heavy deposit of this material resting against the shorter hydrospires near the upper right-hand corner probably represents a partially filled intestine.

sion of the plate was not so rapid as its upward. It required also the gradual filling in of the older position of the hydrospire slit or pore. The filled in material did not reach the outer surface of the plate and the external furrows thus lie directly over the internal grooves. That the filled in portion was the weaker and more readily dissolved in weathering seems to be shown by the widening of the slits of the lower margin in all plates found in a detached condition. This widening is shown in the figures of plate 5 save in the fragment protected by its bibrachial at j.

During the downward extension of the older hydrospires there appears to have been a widening of their bases to correspond with an increase of function. This was accompanied not only by the inward bending of the plate toward the center of the theca, of which it may have been in part the cause, but also by the throwing of the outer ridges between the slits into a marked zigzag and giving them a still stronger external thickening near the suture.

There was no marked thickening of the plate after the addition of new sheets of stereom at the edges. Young plates are somewhat thinner than the old plates but the latter are thinner near their centers. The structure of the ambulacrum, having at least in places, four plates in a line across the edge of the deltoid, necessitated a rather thick sutural face for even young plates. This thickness was gradually increased at the lateral edges of the plate as is shown by figure 2.

The increased growth at both ends of the hydrospires and the thickening of the plate was accompanied by increased growth in depth of the hydrospire membrane; the oldest portions or that under its place of origin becoming the deepest, hanging far into the coelomic cavity, and giving a triangular outline to the structure when viewed from the side. To enable them to make this continued growth these structures must have had their inner edges remain membranous. No primary calcification is apparent in the cross-section, their outlines being seen only as a fine, rather interrupted line of carbon particles. The portions of the membrane next the plate became strengthened by the deposit of calcareous matter, but the whole structure was so delicate as to be rarely preserved. Plate 5, figure n, has a small area showing the outer edges of these thin hydrospires still attached to the plate. Another fragment of a deltoid shows them in a still more perfect state of preservation but so filled in with rock deposit as to show but little in a photographic

enlargement and it is therefore not figured. Under the microscope the specimen shows the walls of the hydrospires to consist of irregularly thickened and corrugated sheets so constructed as to give strength with use of very little material and so secure the thinness necessary for the exchange of gases with the sea water. The slight bending of the inner ends of the older hydrospires in figure 2, the loss of the inner edges of several of the larger and the detached and shifted edges of others, indicated by arrows, all point to their membranous character and their tearing during decay.

The addition of brachioles and hydrospires while consecutive was broken by periods of rest, and "growth lines" so formed may clearly be seen in plate 5, figures h and i, the older deltoids being easily recognized within their newer margins.

The younger, thinner deltoids show vertical grooves on their upper surfaces which lie over the hydrospire grooves below. The thicker additions made to the edge of the plate by the upward growth of the newer brachioles soon mask their external parallelism and give rise to a series of external ridges running at right angles from the lateral plate margins.

It would seem that young plates having but 12 hydrospires could hardly have had any portion of their bases supported by the bibrachials. The interbrachial plates alone would support the lower edge of the deltoid and the form viewed axially would be simply pentagonal, without the asteroidlike projections, or as in Troostocrinus.

The increase in width of the deltoid would be accompanied by increase in length of the bibrachials. Their peculiar form is thus in part brought about by the greater growth at their distal ends. It may be noted that this extension has constantly carried the distal end of an ambulacrum farther away from its radial plate. Earlier stages in development would show that closer proximity possessed by its ancestral forms and from which the Eublastoidea with their notched radials took a divergent line.

A comparison with Codaster leads one to the conclusion that the deltoids, in their origin, were true deltoids or orals.

I may have asserted rather too positively that the hydrospires lie in the grooves on the inside of the plate. In the cross-section of the deltoid the boundary between the coelomic cavities and the plate could not be readily made out. The outer ends of the hydrospires are clearly marked by carbonized lines convex out-

wardly. These are without doubt very near the inner boundary of the plate. There exist in this cross-section more faint and diffuse lines of scattered carbon particles that connect these outer ends of the hydrospires with each other and where the lines can be distinguished they seem to lie on the whole a little nearer the exterior of the plate. This gives one the impression that the hydrospires rested on the internal ridges rather than in the grooves. The fact that the basal hydrospire slits open directly into the grooves seemed to me to negative such a conclusion. The weaker carbonized lines probably do not mark the inner boundary of the plate but show the outer folds of the membrane forming the hydrospires. If we imagine a series of folds formed as in figure 3 of the text with their outer edges

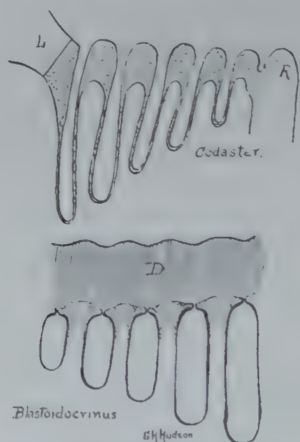


Fig. 3 A diagram of the hydrospires of Codaster copied from F. A. Bather's The Echinoderma [part III of A Treatise on Zoology edited by E. Ray Lancaster] p. 83, and a hypothetical diagram to show probable manner of formation of the hydrospires in Blastoidocrinus.

thrown very closely together and adhering in part before stereom formation took place and if we further suppose that stereom was formed more abundantly at the outer folds as in Troostocrinus and Codaster, while at the same time the outside was covered by the thick stereom built above the fold along that wide face of the deltoid supporting the four rows of plates before mentioned; then we shall find a condition of things not only as shown in figure 3 but also actually existing in figures k, l, m, n and o of plate 5 where the ridges are seen to be narrower across their upper edges than the distance across the groove at the same level.

The inner surface of a deltoid is not often seen in as perfect state of preservation as in the material photographed for these plates. The dark calcite, showing the presence of carbon, does not seem to weather so rapidly as pure calcite. This differential weathering has often left the plates in great perfection. The extra deposit of carbon then at the outer closed edge of the hydrospire fold should tend to preserve it, while the less carbonized filled in ridges between the hydrospire folds and representing the inward thickening of the outer fold would be more rapidly dissolved away and thus leave the more uniform smoother condition usually found. If this idea of the plate extension be correct the stereom of the plate can hardly be said to be folded. The advantage of closing the outer slit of the fold save at its extreme ends will be manifest and the flow secured by connection with the food groove of a brachiole gives us a very effective organ of respiration. Reduced to their lowest terms these hydrospires seem to be diplopores added to a plate through an inward fold of ectoderm and coelomic epithelium at a suture and bridged over across the outer middle of the opening to form a sac with two external openings or pores. In true diplopores there was no extension of the sac and the openings soon became included by the continued growth of the plate around them. In pectinirhombs the fold crossed the suture, a probable extension of the membranes occurred and therefore a separation of the pores through plate growth, the extending lines still indicated at the surface as in Pleurocystis, or obliterated as in Schizocystis. Hydropores of the form of Blastoidocrinus seem to be derived from the diplopore type from plates supporting brachioles and thus coming to be associated with the power to maintain a marked flow of water, in which case the neglect to follow the established and inherited rule to close the plate around the pore would be a " weakness " tending to insure survival and the pores would thus come to lie at opposite margins of the plate.

Brachioles. The brachioles start out at nearly right angles to the edge of the deltoid but at the sixth external plate [the first row shaded or darkened in fig. 1] the brachiole assumes a nearly vertical position. The brachioles at the apex are the oldest on the deltoid and are also the longest, being 6 mm long in the specimen figured, and thus as long as one fourth of the extreme hight of the specimen. These oldest brachioles and some six to eight others on each side of them show on their outer surfaces two rows of alternating plates some 60 in number.

Farther out on the ambulacrum the brachioles possess this outer biserial arrangement between the first and the eighth but after this are uniserial. The larger drawing of the seventh brachiole at a in figure 1 shows a transitional form. These newer brachioles show from 17 to 30 external plates. Each brachiole, with the exception of the two oldest, starts with a single large kidney-shaped plate very slightly less than .5 mm in longest diameter. This is surmounted by two plates in which the lower or distal is much the smaller; the next two plates above this are of nearly equal size and of the pair that follows these it is the upper or the one nearest the axis of the theca that is the smaller. It appears as if the outer smaller plate of the first pair became the foundation plate of the arm. The law of biogenesis would indicate that biserial brachioles preceded the uniserial but the change in this instance may be caused by a rotation of the brachiole to the left on its own longitudinal axis, as is indicated at A7 figure 1 and by other earlier brachioles of this specimen, bringing the left-hand plates of a biserial arm to the front and making the arm appear uniserial. The diagonal sections of the lower brachioles in figure 2 show in places a section through a pair of plates and the structure near the base of the brachioles suggests the arrangement of the side plates and outer side plates of Codaster.

Where the upper brachioles have been turned away from the wing plates, as shown in plate 3, lower figure, at a, the older brachioles seem to have had an additional row of plates on either side and alternating with the outer or back plates. A cross-section of one of these brachials would give the form of a parallelogram with its long axis set at right angles to the surface of the wing plate. The middle two fourths of the rear wall consist of a double row of very small, alternating, covering pieces. The cross-section of the lower parts of the newer brachioles seems to show only the back or outer plates (the end of but one of them seen from the outside) with greatly elongated sides and with traces here and there of what may be small covering plates.

One brachiole in the anal interradius seems to have been certainly free from the others for its entire length but the brachioles with apparently uniserial back plates have their margins zigzagged as if they had become bound, each to its neighbor, at their sides. This may not have been true of all the upper brachioles but where some of the older ones have fallen away from the wing plate, as in plate 3, lower figure;

the evidence seems to favor the idea that these brachioles swung out as one continuous sheet and that the outer edge of this sheet was subsequently broken away. This feature reminds one of the arm of Cleiocrinus, a species of which I have found in the same bed with Blastoidocrinus, and is another good example of homoplasy. How much of the base of this sheet could leave the internal plates of an ambulacrum is another question. It seems to have been fixed at least up so far as the eighth row of back plates.

There remain for description some brachioles apparently four in number, attached not to the deltoid but to the upper ends of each pair of bibrachials. These appear to be biserial, and are so at least in part, but they are small and tapering and the arrangement of these plates is made out with exceeding difficulty. The inner two are still more tapering and rudimentary in character. They also possess no perfected hydrospires for the bibrachials are destitute of any such structure. Are these *old* brachioles remaining attached to a plate that once possessed a hydrospire system or are they new brachioles in the building? If old, then the new brachioles must be formed between the more mature outer ones and the last brachiole on the deltoid; if new, they must be constantly pushed to the side by still newer additions and one by one take their places on the deltoid. There is no evidence to show brachiole formation between these and the deltoid but these grade very regularly into the more mature forms and there are a number of brachioles with their basal single plates still half on the bibrachial and half on the deltoid. The fact, already mentioned, that these lowest plates make practically no increase in size after being given a position on the deltoid, is of itself significant in this connection.

Adambulacrals. Between the deltoids the coelomic cavity is completely roofed over by an arched wall, concave inwardly, consisting of a double row of alternating (?) adambulacrals. These plates, seen from the side, are somewhat in the form of a parallelogram with the longitudinal axis about twice as long as the transverse axis. The two long sides are slightly but very regularly convex toward each other; each of the two ends bears four obtuse angles. The middle face of the outer end rests against the inner edge of a deltoid; the face below this sinks into the coelomic cavity and is parallel to the short side of the brachial end of a hydrospire; the outer face of the same

end rests against one or more small plates apparently forming a double row down the middle of the edge of the deltoid and just inside of the apparently single kidney-shaped foundation plates of the brachioles. These small plates, with probably some others, serve to floor a rather large brachiolar cavity which is represented in figure 2 by shading its boundaries. The section, which is rather thick, admits much light over this area and thus suggests a series of connected brood chambers. The boundary plates of this cavity require further study. The inner end of an adambulacrum has one face against a covering plate, a middle concave portion bounding nearly a fourth of a circular food groove, and an inner or lower face that abuts against the opposite row of adambulacrals.

Between each plate and its neighbor in the same row there are two openings, one into the food groove along the line of juncture of the upper, inner faces of the plates and one into a hydrospire along the line of juncture at their outer or deltoid edges. The plate is grooved from the middle of the longer concave upper surface toward the food pore on one side and again from the same middle portion toward the hydropore (?) on the other side. This gives the appearance of a little twist to this outer long edge of the plate and shows that the brachiolar chambers along the side of an ambulacrum were probably connected with each other. The older plates retained the power of extension of their stereom and the upper figure of plate 1 will show that the older became the larger and very materially widened the ambulacrum. These plates rather strongly suggest the ambulacral plates of Asterias.

There is no trace of a lancet plate and perhaps the question of homogenesis of bibrachials and lancet plates is worth considering. Our species has little to offer, but its bibrachials partly separate the deltoids and reach the primary meristem of a ray at one end, while the other abuts against the apex of a radial. This is closely the position of the lancet plate in Codaster. The lancet plate of Eleutherocrinus with its seemingly double oral ends would suggest that possibly the primitive lancet plate was double.

Covering plates. The covering plates of an ambulacrum are remarkably large and heavy. Each is as wide as the adambulacral directly over which it rests and its thickness is extraordinary. The outer or side surfaces of a row are slightly concave and very smooth; against these surfaces rests a portion of the brachioles.

The upper surfaces of some of these plates may be seen in plate 1, upper figure, and an impression of these surfaces in plate 6, figures k and l.

Wing plates. Along the center of each ambulacrum and between the upper portions of the two rows of brachioles but rising a little above their closed tips, there is a linear series of three somewhat razor-shaped plates with their broad and slightly concave backs uppermost. I have called these wing plates and have outlined the exposed surface of two rows of them in figure 1 of the text. In plate 6 at a, b, c and d, are different views of four first wing plates; b and c show outer surfaces [the proximal end of c is probably the lower end of the figure]. These plates lie nearest the anal piece and are the shortest. At e, f, g and h, are different views of four second wing plates. At i, j and k are different views of some third wing plates; k shows the impression of the tops of the covering plates which are more clearly shown at l, which is an outline drawing of the same face of the specimen. These last become longer than the second plates and usually terminate the row. In the specimen figured on plates 1, 2 and 3, the knife-bladelike points of these curve down to and touch the smallest end brachioles of the ambulacrum.

Figures b, f and j show surface ornamentation due to additions through growth. The first wing plate, b, was the first of its series formed and additions were made principally at its sides, its base, and its distal end. The original small second wing plate may still be clearly seen as the innermost V in figure f, and six additional periods of growth have left the arms for six additional V's or rounded ridges. This plate seems to have attained its full length at the end of the third of these seasons and thereafter only increased its hight and width. Figure j shows the same process of extension of the third wing plate and older specimens may have added a small fourth. Figure k seems to be a third wing plate that did not terminate the row. The hollow or grooved upper surface, shown clearly at d, was produced by an upward extension of the edges of the plates to keep just in advance of the extending tips of the brachioles. Figures c and g show a labyrinthine surface ornamentation much like that found on the proximal third of some radials. Traces of the same may be seen at b. In c the growth lines are very nearly obliterated, in g one does not detect them.

Water vascular system. Frequent reference to the respiratory system has been made during the description of some of the more prominent structures involved. There remain however some points which seem to be worthy of further notice and which are now presented. The 17th hydrospire of figure 2 extends into the coelomic cavity more than six times as far as the second; it is also more than 12 times as long as the functioning new ones. Its area presented for osmosis is therefore at least 36 times as great as that of the smaller ones. This would mean that in order to serve the function of respiration as well as the younger hydrospires, the flow of water would have to be 36 times as great. A large sheet charged with carbon dioxid and with the loss of nearly all its dissolved oxygen would be valueless to the organism, yet the continued growth of these old hydrospires would emphatically indicate increase of function.

That there was an increase of function is also shown by the deposit of exceedingly fine sand or clay colored by limonite which we find to be greatest along the inner edges of the largest hydrospires and which is represented by cross hatching in figure 2. This deposit seems to have been swept in just before death and after the falling of the theca to the sea floor.

The flow of water was down the brachioles into the brachiolar chambers, which also show the presence of the same yellow deposit on their walls, and from here to a small extent through the openings to the food grooves and so on through the enteric cavities; but to a very much greater extent (and freed of its food content) through the pores opening into the hydrospires and out at the base of the deltoid. I have before referred to the evidence of greater functional activity at the middle of the base of the deltoids, and the upper row of interbrachials may also be associated with this function. In fact the appearance of this upper row is remarkably suggestive of gradual increase in number at their ends. Whether the hydrospires pass under this row or not is as yet unknown.

The comparatively slight difference between the older and the newer brachioles and the very probable great difference of water flow in the corresponding hydrospires are suggestive of openings connecting each brachiolar chamber with the others of the same row (of which we have already had evidence) and of a marked flow of water through them toward the peristome but remaining outside of the probable covering plates of that area. This arrangement would secure the required greater flow for

the older hydrospires and the marked widening of the ambulacrum toward the same area in this species (and in Asteroblastus and related forms) is to me indicative not alone of the required slight increase of size of the food groove but also of the increase of the functions of respiration and reproduction.

At certain points in grinding down the section shown in figure 2 there was visible a small rather square figure outlined by carbon particles and lying directly under the inner ends of the adambulacrals. This suggests a radial water canal which may have been connected with the hydrospires through side branches. If this additional structure existed the similarity between this ambulacrum and that of an asteroid would be extraordinary, the hydrospires being comparable to ampullae and the lining of the brachiolar cavities to podia.

Anal piece. The wing plates radiate from a high central star-shaped plate apparently formed from five consolidated orals or from five upper or orad portions of the deltoids as shown in figures of Asteroblastus where the food grooves are made to pass over the outer edges of a starlike central portion which resembles in a very remarkable manner the central piece of Blastoidocrinus. In the latter species however the food grooves lie on a horizon but little above the bases of the brachioles or at a depth below this apical piece equal to the sum of the extreme depth of a wing plate and the hight of the massive covering plates. A reference to plate 2 will show how far down this must be. The apical piece stands in the same relation to the covering plates of the peristome as the wing plates do to the covering pieces of the food groove. There is plenty of room under this piece for a series of covering plates as in Nucleocrinus but with the anus thrust through them and by a bend above them opening laterally at a surface flush with the grooved side of the plate and just back of the peculiar brachiole of the anal interradius. Thus the apical piece might better be considered as formed of fused anals than of fused orals. We may note that it is possible that the anus had no external opening. If echinodermal respiration may be in part effected by water entering the alimentary canal by either mouth or anus (as in the "respiratory trees" of holothurians, the "accessory intestine" of echinoids and the "ventral sac" of crinoids) we may possibly have here a somewhat similar condition of things in which there is a flow from the rectum over the covering plates of the peristome and swept away through the older and larger hydrospires.

A series of sections or the gradual grinding down of the oral portion of the specimen figured in plates 1, 2 and 3 would no doubt throw much light on this subject but it seems better to await the finding of other fragments rather than to further mutilate so perfect and unique a specimen.

Views of these fused anal plates may be seen in plate 7. Figures a to o represent the under surfaces of a series arranged according to probable age, an ontogenic series. The piece is at first rather thin, its vertical axis less than half of its horizontal and showing no sign whatever of a central perforation. The piece at a is tilted a little to show its thinness. Figures b, c, d, e and g show the beginnings of an indentation which becomes very marked as the piece increases in age. The more mature pieces l and o show also other indentations. The piece has grown principally by additions to its under surface and to a less extent to its edges. The deeper indentation is rather suggestive of a bend of the rectum, the anal interradius being perhaps the lower in the figure. The interradial indentations in figure o may be the impressions of plates covering the peristome. Figures p, g and x are of upper surfaces showing the grooving caused by increased upward growth due to more extended additions to the plate edges as in the wing plates. Figure g is the anal piece of a regularly four rayed or tetramerous specimens while figure x is of a specimen having its anal piece of six fused plates and possessing a small sixth ray. The vertical axis of these pieces is increased in some specimens to nearly three times their horizontal diameters.

Stem. Billings described the stem as "round with an alimentary canal so small that often the detached joints seem to have no central perforation . . . the flat faces of the separate joints exhibit strong radiating striae." The diameter of the stem of the specimen shown in plate 1 is 3 mm while the joints themselves have a thickness of about 1.4 mm as may be seen in plate 3, upper figure. The last joint left on the stem fragment of this specimen seems to be split across in a direction nearly parallel with the plate face and while it shows a central perforation about .3 mm across, or one tenth of that of the stem diameter, it does not show the strong radiating lines mentioned by Billings. Associated with the fragments of this species, however, are stem joints and roots shown in plate 7, figures r to w, which do show these lines. These stem joints are not abundant here and this would indicate a short stem. I have found no evidence as yet that the stem pene-

trated the theca to the depth figured by Billings and so deep a penetration in his specimen may have been the result of partial crushing or deformation due to pressure.

Taxonomic position. Before attempting to discuss the position of this curious species with its approximately 50,000 plates and ossicles it may be well to point out that the close to 90 plates of its aboral surface do not necessarily point to a generalized type of low rank.

A period of stress developed the many centers of stereom formation and the numerous and irregular plates of a form like Eocystis, but protection in this direction once secured in its adjustment to its environment, there could occur the passive loss, through the mechanism of inheritance, of a plate or so at a time and the others would simply extend their surfaces a little more to keep up a compact exterior. New crossings would tend to replace loss, but a Mendelian factor has entered that tends to simplicity and though loss be slow it is nevertheless sure until it begins to interfere with some other function. Thus the few thecal plates of a Cryptocrinus are indicative of a higher genetic position. A period of stress for some other function would require response or extinction and again lead to proliferation of parts as in stem or brachiole development. The law briefly expressed is that the quiet of an unexacting environment for any part leads to numerical or other simplicity of that part, and that the stress of an exacting environment, on still plastic parts, leads to gain in numerical or other complexity of that part.

Our form seems to have been living in a period of stress in relation to respiration and reproduction. We therefore find five points of what we may call primary meristem, developing adambulacrals, covering plates, wing plates, brachioles, plates lining brachiolar chambers, and hydrospires; and exciting the neighboring deltoids and bibrachials to constantly add to their area. This increase of area to the strong bibrachials would tend to lift the oral surface away from the interbrachials. These interbrachials are away from the points of activity and any extra activity on their part might lead to serious interference with the larger water exits of the deltoids. Release of pressure would render the water outflow the easier and in the membranous margins of the extending ends of the hydrospires new centers of stereom formation would naturally arise and fill in a series of plates representative of the external stereom thickening of the hydrospire folds of Codaster. The result would be a partial fourth circlet of supplementary plates, either homologous in part with the stereom formation of the inner surface of the

deltoid [as in fig. 3] or from new centers of stereom formation and therefore homologous with no plates whatever. It is very highly probable that these plates of the fourth circlet are associated with respiration and that there is a regular increase in their number, newer plates being formed at both ends of the row until as many as 20 were formed in each interradius. The remaining plates of the aboral surface and the five single interambulacrals of the oral surface are really indicative of a rather highly specialized type.

The anal piece, the wing plates, and the brachioles of our genus might perhaps cover an oral surface much like that presented by Asteroblastus and its large number of thecal plates and very remarkable apical piece are suggestive of relationship. Our genus however possesses no diplopores and the remarkable differentiation of the plates of the aboral surface and the unique system of hydrospires clearly separate it from the Protoblastoidea of Bather (1899). The resemblance of the central plates of the oral surface of one to those of the other, seems to be but another example of homoplasy.

While the deltoids of Codaster offer some remarkable resemblances to the genus under discussion, we may note that our form still has more than "the normal definite number of plates"; the hydrospires do not cross over to the radials; the radials not only are not notched but they are not even in contact with either deltoids or ambulacra, being separated from both by the peculiar large and long bibrachial. The structure of the ambulacrum with its adambulacrals spanning the space between the deltoids, the absence of a lancet plate, and its peculiar wing plates and anal piece offer characters more than sufficient to separate the form from the Eublastoidea [Bather, 1899].

The structure of the ambulacrum on the other hand would at once suggest a position with the Edrioasteroidea as would also the torsion of the oral over the aboral areas of some 7 to 10 degrees toward the right, but the presence of brachioles, not to mention other differences of structure, would exclude it from that group.

The form seems also to suggest several rather remarkable crinoid affinities. Here we have the marked basal invagination of many forms, the strongly crinoid radials, the group of interbrachials, and at least the suggestion of brachials in the pairs of plates assuming that position. These characters all exist on a differentiated aboral surface and the structure rather closely resembles the crinoid cup. The oral surface is just as extraordinary. Here we have the crinoid tegmen with its five deltoids as in Carabocrinus, its introduced anal

plates, and its food grooves with their covering pieces leading to the mouth.

We must not make too much of the absence of true brachials. The primary meristem in our species has already formed just such a linear series of single plates (the wing plates) on the upper surface of a ray. Does this radial series of single large plates give an excuse for the announcement of a new class of Echinoderms separate from all others? We may imagine our primary meristem to start a new wing plate and then push up between it and the last formed. This would give an outer brachial to a now ascending uniserial arm. It would also require but a slight modification of the structures formed by this meristem to produce an ascending biserial arm with its fringe of pinnules. The ascending arms would at once retire the tegmenal brachioles from service and the modification or loss of these and adjacent structures would follow. In my description of Carabocrinus geometricus,[1] I suggested that the tegmen had plates bordering the lateral sides of the deltoids and thus underlying the food grooves. Figure 2, plate 1, of that report would suggest such a condition but the figure does not do justice to the specimen. The notches for the bases of the deltoids are more regular than in the figure and the angles at the corners should have their outer sides running parallel with the lines taken by the missing food grooves. These bordering plates might be homologous with the adambulacrals of Blastoidocrinus.

The affinities of this genus seem to associate it most clearly with the Blastids but under neither grade as defined by Bather. I propose a new order for this genus under the name of Parablastoidea and with the following characters.

PARABLASTOIDEA

Blastoidea with the theca more or less clearly separable into an oral and aboral surface. The aboral consists of three or more circlets of plates. Basals (unknown); five radials, in contact all around; five pairs of plates over the radials and supporting the distal ends of the ambulacra (bibrachials of Blastoidocrinus), and between them and completing the third circlet a group of smaller plates (interbrachials of Blastoidocrinus) arranged in one or more transverse rows. The oral surface possesses normally five ambulacra without a lancet plate but with adambulacrals meeting under the food grooves, with covering plates and with numerous

[1] N. Y. State Pal. An. Rep't. 1903. p. 282.

brachioles. Respiration by means of hydrospires crossing one or more interambulacral plates, the water flow passing down the brachioles into a series of brachiolar cavities from which the hydrospires are reached through pores passing between the adambulacrals.

Pachyocrinus crassibasalis Bill.

Can. Org. Rem. Decade IV. p. 22, pl. 1, fig. 3 a-b

The wing plates of Blastoidocrinus and its closely terminal anus remind one strongly of some species of Eucalyptocrinidae and the resemblance is no doubt due to homoplasy. As we have in the Chazy limestone a form of crinoid which may also have possessed

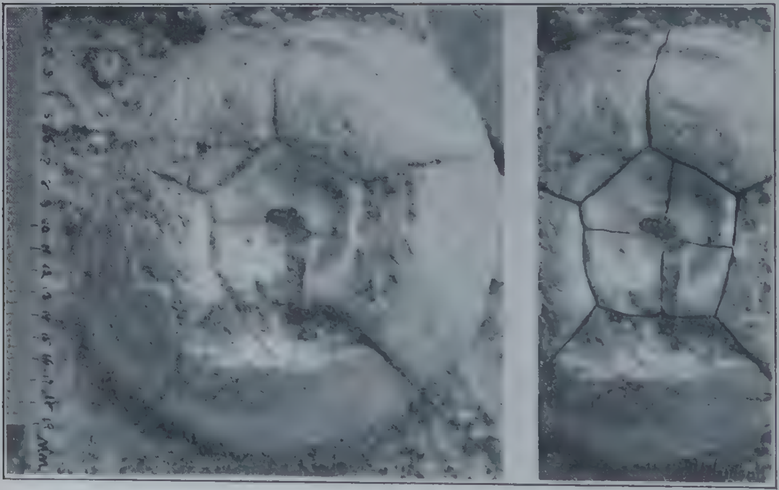


Fig. 4 To the left, a reproduction of an untouched photograph of Pachyocrinus crassibasalis. To the right, a portion of same with the sutures lined with ink. It will be seen that the specimen has but four basals. The five heavy radials still have their upper edges buried in the matrix.

similar plates and as Mr Billings immediately followed his description of Blastoidocrinus with this still more difficult puzzle it may not be out of place for me to here again call attention to this neglected species.

From the accompanying cut [fig. 4] it will be seen that this form has four basals, not five as Billings describes and figures it. Figure 4 is reduced from a photographic enlargement of the type specimen, the portion of the figure to the left is untouched, at the right is a part of a print from the same negative with the sutures darkened with ink. Billings says of the heavy plates that they "may be either subradials or first radials," which in our modern terminology

would read "either basals or radials." They are undoubtedly radials and crassibasalis is rather a misnomer. The specimen should have been named crassiradialis and it seems to belong to the Eucalyptocrinidae. It would, I believe, be possible to uncover the edges of these radials and thus determine the number and something of the character of the third circlet of plates. I am deeply indebted to Dr J. F. Whiteaves for the loan of this specimen and I have figured it here in the hope that some one may lift it out of the list of indeterminable names. The genus and species are both good and the form must be reckoned with in the future study of these interesting primitive groups.

DEOCRINUS gen. nov.

δέω, to bind; κρίνον, a lily

Genotype Rhodocrinus asperatus Bill.

Calyx globose, with a rather narrow and shallow basal concavity, involving the small interbrachials and about one third, or less, of each basal. Primibrachs two, *second* secundibrachs are unsymmetrical, secundaxils each giving off a large pinnule with very deep ambulacral grooves, which is incorporated with the cup and the first ossicle of which meets its opposite neighbor over the topmost interbrachial in each interradius: the *first, third* and *fifth* secundibrachs are nonpinnule bearing; all subsequent brachials bear pinnules and the first two of these have also become a part of the cup or meet to form a weblike extension of the bases of the arms.

Arms, so far as shown, but two to each ray, the brachials uniserial at least up to II Br_9, beyond that unknown; one or two intersecundibrachs are present in each radius. Tegmen composed of some hundreds of small rounded pebblelike plates extending out over the ambulacral grooves of the lower pinnules and the base of each arm. Anus nearly central and having a tube whose stout lower plates are arranged with their long axis radially disposed. Anal interradius differing but little from the others.

Remarks. "Archaeocrinus has a more elongate calyx . . . has no anal tube, and never supplementary pieces"[1] in the interradii such as we find in the genotype of Deocrinus. There is also an absence of the median ridge over the brachials in this genotype and the upper interbrachials do not "connect imperceptibly with the plates of the disc"[2] but the plates of the tegmen are separated

1 Wachsmuth & Springer. The Crinoidea Camerata of North America, p. 250.
2 *Ibid.*

from the interbrachials by the meeting of the first pinnules of each arm with those of its neighbors.

The last character also separates the genus from Diabolocrinus and in addition the tegmen is not composed of "rather large plates" but of numerous very small ones.

The incrusted and imperfect condition of this unique genotype which for nearly 50 years has remained the only specimen of the Rhodocrinidae found in the Chazy fauna has caused it to be rather neglected and as yet a good plate, a fairly full description, or a cup analysis of it has not been published. The two additional species of this family published in the report of the State Paleontologist for 1903 and the three new species which follow seem to demand a more complete description of this interesting first species of Billings and I therefore offer the following:

Deocrinus asperatus Billings (sp.)

Rhodocrinus asperatus Billings. 1859

Plate 8, figures a and b; cup analysis figure 5 of text

Diameter of calyx across zone of primaxils 12.5 mm, narrowing above to 11 mm at level of tegmen; lower half of cup a hemisphere; diameter of basal concavity 4 mm.

Infrabasals with their inner ends bent upward at right angles forming a tubular chamber appearing to be a continuation of a large circular stem lumen 1.5 mm in diameter; the outer horizontal shoulders of these plates bear the impression of the proximal stem joint 2.5 mm in diameter [fig. 5]. Each plate bears a faint raised central, radial ridge representing a suture of the proximal ring and on either side of this there are eight or nine short cuneiform elevations making a well marked outer circlet, within which is a second circlet of fainter radial lines.

The basals may be divided into three transverse portions: first, a rather smooth concave inner third, forming the outer portion of the basal concavity, bent at an angle of about 90 degrees with the middle portion of the plate and bearing only very faint and short radial lines, the boundary marked by a strong raised ridge, these ridges making a well marked basal pentagon with the rounded angles on the plates; second, a rather smooth outer fourth, bent inward at an angle of about 45 degrees and forming a concave margin to the plate ornamented only with numerous extremely fine, raised, irregular ridges usually running toward the interradial plates; the boundary of this portion marked by a well defined raised ridge concave toward the base of the plate; in other Rhodo-

crinidae this ridge usually is continued as an unbroken line along the margins of the radials and brachials up to II Br_1, but in this species is broken once or twice on the basal, is lost at the sutures, and appears along the other plates only as a series of rough, elongated tubercles; third, the middle portion of the plate shows a few

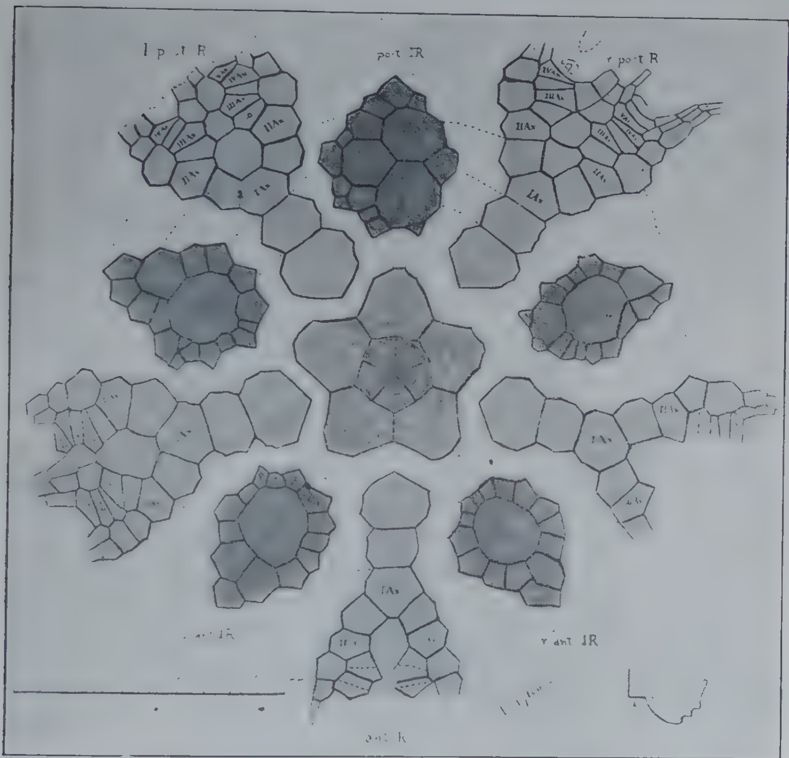


Fig. 5 Analysis of *Deocrinus asperatus*. The basal and interradial elements are shaded. Between the interradial sutures of the infrabasals the raised casts of the sutures of the proximal stem joint have been faintly indicated. In the lower right-hand corner is an outline of a vertical section through a basal and an infrabasal. The shoulder of the latter which bears the impression of the proximal ring of the stem is shown at C.

prominent raised tubercles on either side which indicate ridges which are also represented on the radials by similar tubercles.

The radials present about the same area as the basals. The first brachial is smaller and bears also a median row of tubercles. The primaxil is still smaller. The first secundibrachs and the intersecundibrachs are nearly the size of the primaxil, the arm plates become abruptly smaller at II Br_2, the first plate of the first pinnules is nearly as large as II Br_2 and is in contact with the three next following brachials.

In all but the anal interradius there is a single large plate completely surrounded and separated from all other plates by from 13 to 14 "supplementary" plates in contact with it. The two upper plates of this circlet are usually the larger and are capped by an additional plate over which meet the first plates of two opposing pinnules. In each right and left posterolateral interradius additional supplementaries increase the total number of plates to 18, the post. IR has two large plates neither of which is completely surrounded by supplementary plates next the r. post. R.

The third plate of each first pinnule sends inward two thin sheetlike extensions, one each side of the very narrow ambulacral groove, that are five or six times as long as the width of the face of the plate and reach more than halfway in toward the center of the tegmen; the plates above this send in shorter extensions and the fifth plate reaches the edge of the tegmen. The second plates of the second pinnules (the first inner pair of each radius) have similar sheetlike extensions; the upper edges of the contiguous sheets of these pinnules are covered with a single row of rather large tegmenal plates.

The tegmen appears to have been supported by a radial series of struts formed in this manner and preventing an inward closing of the bases of the arms; the tegmen would thus be rigid, not flexible, and would be nearly flat, the arms closing over it.

On a level with the upper edge of the first plates of the third pinnules and midway between them and the top of the second plates of the second pinnules there is a rectangular opening into the calyx (10 in all) and a little distance above this is another and larger channel, the food groove, directly roofed over by the small plates of the tegmen, and the ambulacral grooves of the third joint of the second pinnule lead into this opening. The ring of larger plates around the anus is not complete but open toward the center of L. post. R.

Remarks. I am again indebted to Dr J. F. Whiteaves for his courtesy in allowing me to give some time to the study of this specimen. I wish also to express my obligation to Mr Walter Billings who sent me a cup analysis he had made of the same, showing about 140 plates.

By removing incrustation from the cup, I have been enabled to represent some 90 additional plates but otherwise my analysis does not differ from that of Mr Billings save in the lost calyx plates of L. post. R. (shaded) where I find indications of but two missing plates where Mr Billings gives three.

HERCOCRINUS gen. nov.

ἕρκος, a snare; κρίνον, a lily

Genotype Hercocrinus elegans

Calyx more or less flattened at the base with a basal narrow concavity involving less than half of each basal; infrabasals very small and completely covered by the column. Radials nearly equal in size to exposed portion of basals. Primibrachs two, first secundibrachs are unsymmetrical secundaxils each giving off a large pinnule which is incorporated with the cup and the first joint of which meets its neighbor over the topmost interbrachial; all subsequent brachials also bear pinnules and the first two of these are also incorporated with the cup or meet to form a weblike extension of the bases of the arms. Arms two to each ray, the brachials of each zigzag up to at least the tenth, beyond that unknown; intersecundibrachs absent. Tegmen of very numerous small plates forming a basin whose margins extend upward on the arm bases and whose center is more or less elevated in a nearly central mound containing the anus. Interradii often differing from each other in the arrangement of their plates, the radials usually separated from each other by two interradials. One or more larger central or eccentric plates more or less surrounded by other interbrachials. Supplementary plates present but not so numerous or so regularly arranged as in Deocrinus. Anal interradius not to be clearly distinguished from the others. Stem circular, lumen about one sixth the stem diameter, pentagonal, the angles at the stem joints and therefore radial in position.

Remarks. Hercocrinus may be distinguished from Diabolocrinus by its narrow basal concavity; its completely covered infrabasals; its interradial spaces do not "connect with the disc plates, or, properly speaking, pass into the disc" [W & S]; the anal interradius is not wider than the others, the ventral disc is composed of very small, not "rather large plates" and the column does not possess a pentalobate canal. The tegmen is more like that of Archaeocrinus but the calyx is not elongate, the arms do not branch and supplementary plates are numerous.

Hercocrinus elegans sp. nov.

Plate 9; cup analysis figure 6 of text

Description of type. Cup 12 mm wide, 7 mm high, base flattened, rather pentangular.

Infrabasals completely concealed by proximal stem joints, basal pit or depression 4 mm in diameter or but little more than the diameter of the stem joints which measure 3.5 mm.

Basals with smooth transverse elevated ridge, angled on the plate, making a pentagonal boundary to the basal concavity. There is a transverse raised ridge near the outer edge of the plate, and between this and the first there are three finer ridges the innermost of which meets the angle of the first mentioned ridge. Between this last finer ridge and the heavy transverse one the plate is depressed, the inner angle of the radial is also depressed and thus two basals and a radial unite to form a well marked depressed

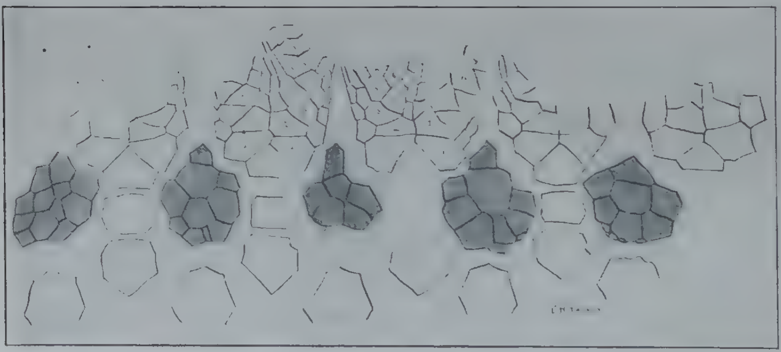


Fig. 6 Analysis of Hercocrinus elegans. The interradial areas are shaded. The one at the extreme left is likely to have some fractures represented as sutures. This side of the theca was crushed in. The fourth interradial area from the left is the one to the front in the upper figure of plate 9. The same interradial area is also the upper of the two interradial areas in part shown in the right-hand portion of the lower figure. The rounded, gemlike surfaces of the plates of these areas and the tendency to form small supplementary pieces is well shown.

triangular pit; one basal is marked by two short lines within this pit, in the others it is smooth. The outermost of these plate ridges crosses the suture and continues over the sides of the radials which are slightly smaller than the exposed surface of the basals. This marginal ridge is about .6 mm from the edge of the plate and marks off an outer depressed, smooth and concave surface (the outermost edge of the radials being again slightly raised where they meet the interradials). Some of the finer lines of the basals after passing over the radials are continued up the brachials in an irregular manner as a fine central line, with here and there others, on a strongly convex medial space which otherwise would be remarkably smooth. The brachials are also edged with a very smooth concave border like that on the edge of the radials.

Interradials and interbrachials with highly convex somewhat polished surfaces resembling a setting of precious stones. The cup analysis, figure 6, shows best the relation of these but in the crushed interradial areas a few of the lines may be due to fractures instead of sutures. Plate 9 will show clearly the appearance of some of these interradial "jeweled" areas.

Tegmen of some hundreds of very small plates running out to and a little over the bases of the arms and merging into well defined rows of covering plates. The tegmen with this extended covering of the arms and pinnules forms a wide and rather smooth basin save for the pointed elevations of the tegmen plates. The tegmen has been crushed in on one side and the structure of the anus is not clearly manifest.

Remarks. This species is closely allied to Lyriocrinus ? beecheri Hudson[1] and the latter belongs to the present genus and should be known as Hercocrinus beecheri. H. beecheri lacks the larger more flattened and pentangular base, the five prominent triangular indentations of which the lower angle of each radial forms a part, and the more numerous convex polished interradials of H. elegans.

Hercocrinus ornatus sp. nov.

Plate 10; cup analysis figure 7 of text

Description of type. Cup nearly globular, greatest width 13.5 mm, at base of primaxils; narrowing above to 11.5 at II Br_2. Immediately above this plate the arm starts outward at an angle of about 45 degrees. From the bases of the primaxils the cup curves regularly downward to a width of 5 mm at the edge of the basal concavity. Vertical hight from base to tegmen 11 mm.

Infrabasals small, completely hidden by the proximal portion of the column. Basals with a rough raised transverse ridge which forms a raised circular border to the rather narrow basal convexity. From this ridge the face of the plates is directed outward at an angle of the cup. In addition to this ridge there is another rough and prominent one parallel with it but near the outer margin of the basals. These plates possess a few shorter ridges and numerous pitted depressions, giving them a rather rough and reticulated aspect.

The radials are but little larger than the exposed surface of the basals, they are also similarly roughened by fine reticulated ridges

[1] N. Y. State Pal. An. Rep't. 1903. pl. 3, p. 277.

with numerous small shallow pits scattered between. Each supports at its apex two very nearly equal interradial plates with usually a vertical suture between them.

First brachials about 2.5 mm wide and nearly square. The outer

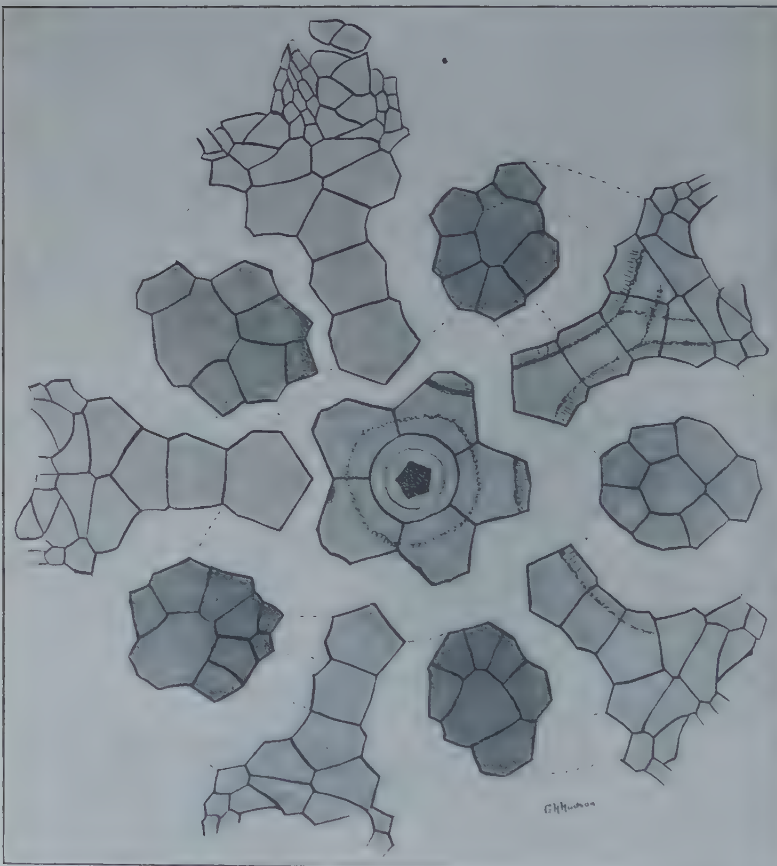


Fig. 7 Analysis of Hercocrinus ornatus. Note that the radials instead of being "separated by a single distinct plate" are separated quite regularly by a pair of nearly equal interradial plates. The depressed plate boundaries and raised ridges have been but roughly indicated. The interradial area to the left of the upper one is the area shown in plate 10. Two depressions across the top of the central plate of this area are strongly indicative of sutures and one of these is represented in part by a dotted line. The photograph made the depressions appear as sutures and they were so drawn for plate 10. The angles of the surrounding plates in this figure would suggest that the arrangement of plate 10 is the correct one. The fine line of the suture itself is often hard to detect.

prominent transverse ridge of the basals is continued along the edges of the radials and brachials and over the outer edge of II Br_1. The whole ridge forms an almost complete, raised boundary about .6 mm outside the edges of the circular or slightly oval interradial

areas. The margins of the basals, radials and brachials marked off by this ridge are depressed and concave. These ridges fork once on the radials near their upper borders and the inner branches unite to form an extremely faint medial ridge on the elevated and flattened surface of the brachials. The outer ridge forks again, rather more prominently, on the primaxils, the inner branches crossing near the upper angles of this plate and thus giving the II Br two prominent parallel ridges each.

The cup plates surrounding the tegmen are very thick and heavy and extend their lateral edges radially inward to the depth of 3 mm, a feature similar to that found in Deocrinus asperatus. Ambulacral grooves very narrow and not showing at all on the lower plates of the first pinnules.

Bases of arms zigzag. Lower pinnules of four or five rather stout joints, each meeting its neighbor with a wide flat face forbidding an erect position of the arm bases. These bases with the arms closed would project outward above II Br_2 at an angle of about 45 degrees with the axis of the cup. For the arrangement of the interbrachials see cup analysis, figure 7.

Tegmen of numerous very small pieces extending outward over the lower pinnules and arm bases.

Anal tube short and stout, about 3.5 mm high; moundlike at its base with a width of about 5 mm; position very nearly central.

Column of nearly uniform circular rings 3.3 mm in diameter with a pentagonal lumen 1 mm in diameter; rings incised about halfway in to lumen.

Genus ARCHAEOCRINUS Wachsmuth and Springer

Archaeocrinus ? delicatus sp. nov.

Figure 8

This species is described from a fragment which is remarkably well preserved and free from incrustation both inside and out, save that some fragments of the stem and a little deposit still partly fill the basal concavity. This concavity is about 6 mm across and nearly 5 mm deep. About two thirds of the depth of this cup is due to five completely fused infrabasals leaving an inner pentagonal opening 2 mm across. All the preserved plates are remarkably thin, that is about one third of 1 mm in thickness, and all sutures are very plainly visible save alone those of this fused cup. Neither sunshine nor compound microscope shows them save

for a trace of external thickening shown on a few interradial lines and designating their position.

Basals five; a depressed distal surface about one fourth of the area of the plate bears about 16 very fine, slightly rough, uniform and parallel ridges which are set at right angles to the edge of the plate and cross over the suture and on to the interradials; from their common suture to this depressed portion there are about 24 similar lines running also at right angles to the edge of the plate and crossing over the suture and on to the radials: the proximal fourth of the plate is bent rather suddenly upward to form

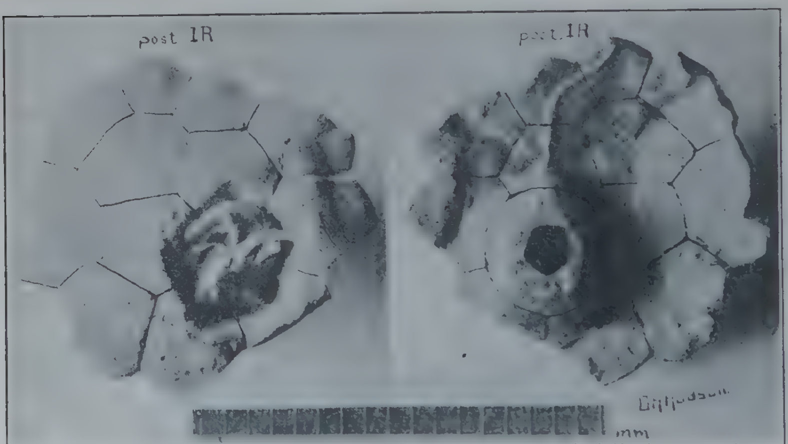


Fig. 8 At the left is a reproduction of a photograph of the exterior of a basal portion of Archaeocrinus? delicatus. The fine, parallel, ornamental lines of the plates are lost in the reduction save in part in one plate to the right where they had been strengthened a little with a fine pen. At the left is a view of the inner surface of the same specimen. Most of the sutures have been lined with ink. The infrabasals appear flat and ringlike in the figure but they really form a deep cup with angled edges and with the plates apparently grown together to form one piece.

a portion of the basal concavity, between this bend and the middle area there is a raised stronger ridge like a V with very widely open arms, the angle turned away from the basal crater and thus forming a portion of a basal pentagonal ridge.

The radials are similarly ornamented with the fine lines, from 8 to 12 to the mm, which are set at right angles to the sutures. The radials are completely separated by large interradials without any supplementary plates. The anal interradial has an extra plate and gives an additional angle to the radial of l. post. R. The cup has a rather wide and somewhat flattened base, the distance across at level of outer suture of the radials measuring about 16 mm.

One brachial shows in l. post. R, but it bears the same ornamentation. The species is easily recognized by single plates, there being no others that can be confused with it. The fused infrabasals and the absence of a median line up the brachials make the generic reference somewhat doubtful. Each radial has a somewhat raised mound just above the middle and if these are connected with lines convex toward the angles of the inner pentagon, they will outline a raised basal portion and partly outline five depressed interradial areas. The species is described here to call attention to an example of fused infrabasals in a member of the Rhodocrinidae and to the internal visceral ridge of the anal interradius. The fused condition of the infrabasals was apparently due to the extreme thinness of the plates. Homoplasy then should perhaps lead us to expect a similar condition of things in Blastoidocrinus and in other species not yet examined.

I wish in closing to thank many of my students and others who have taken an interest in this decomposed material and have given me valuable help in assorting the same, and I wish also to thank Dr John M. Clarke for the loan of literature connected with the subject and for numerous other courtesies.

PLATE I

EXPLANATIONS OF PLATES

Blastoidocrinus carchariaedens Billings (sp.)

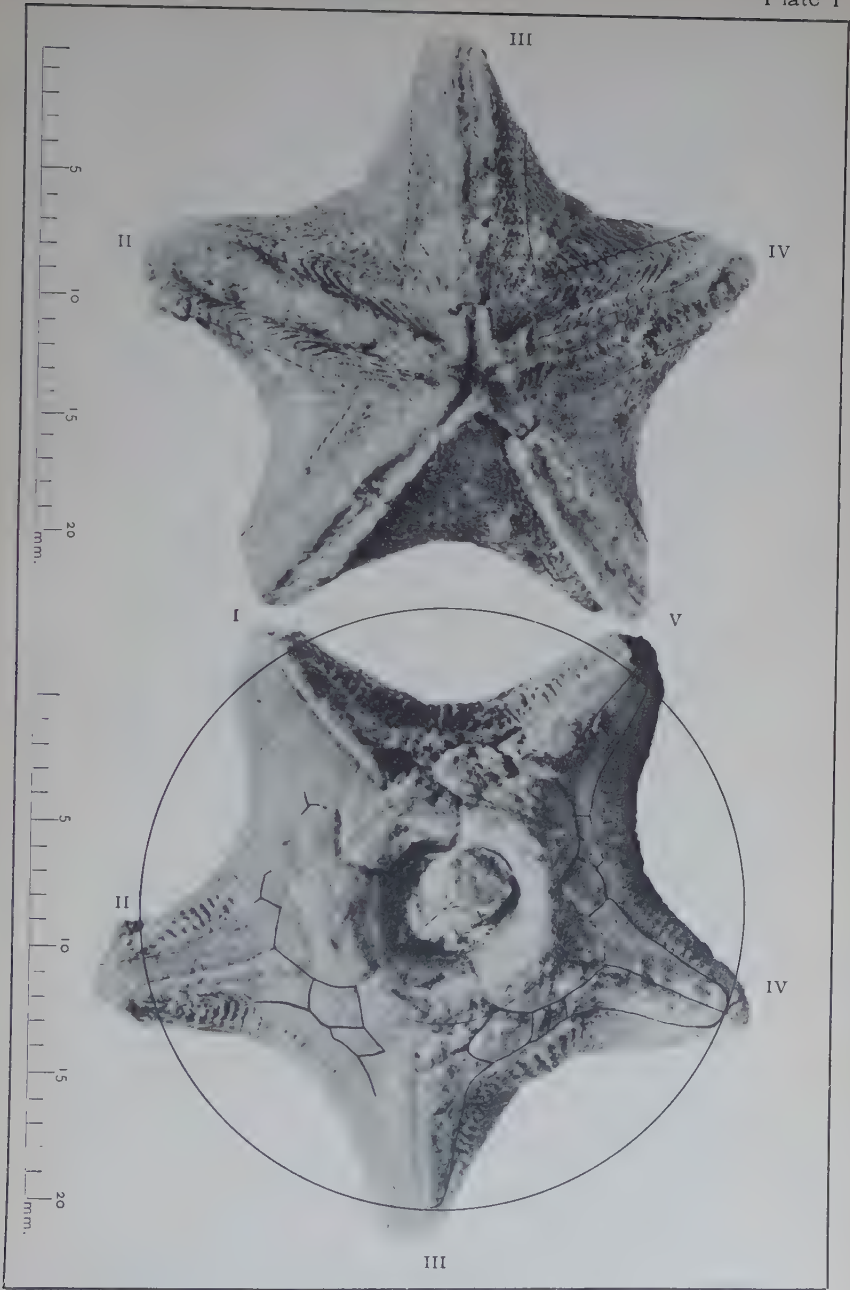
Page 97

The upper figure shows the oral surface with its star-shaped apical piece. The wing plates were lost from ray IV exposing several of the covering pieces. Six of these and the outer boundaries of the double row were partly outlined with ink on the original photograph. Although the figures have been reduced to less than half the diameter of the originals, additional boundaries can still be detected. The upper boundaries of the deltoids were also marked.

The lower figure shows the aboral surface of the same specimen. A few of the sutures were lined with ink on the photograph. Pencil marks used in finding the center were allowed to remain and two circles drawn from this center. On the outer of these, small portions of extended radii were marked to show the slight displacement of the rays. With the exceptions mentioned there has been no retouching of the photographs.

The original is from a yet undetermined horizon of the Chazy limestone of Valcour island, Lake Champlain, but the position is probably near the upper portion of the middle beds.

The specimen is in the possession of E. M. Hudson.



G. H. Hudson, Photo.

PLATE 2

Blastoidocrinus carchariaedens Billings (sp.)

Page 97

A side view of the specimen figured in plate 1. The wing plates with adhering portions of the brachioles had been broken from rays III and V. These were replaced for the photograph. A few of the sutures and a small part of the system of brachioles were marked that they might be reproduced with greater distinctness.

G. H. Hudson Photo.

PLATE 3

Blastoidocrinus carchariaedens Billings (sp.)

Page 97

Two views of the specimen figured in plates 1 and 2, showing different interradii; a few of the sutures marked with ink.

At a in the lower figure may be seen the edge of a sheet of brachioles which are bent away from the broken wing plate. In the larger photograph this edge shows traces of an inner row of side pieces. At b the deltoid is much worn, as if the plate had been rubbed against some interfering object during growth. The section of the deltoid with its hydrospires and two bounding ambulacra was made at or very close to the dotted line c

G. H. Hudson, Photo.

PLATE 4

Blastoidocrinus carchariaedens Billings (sp.)

Page 97

Figures a–f are of radials of different ages viewed from their bases and showing radiating grooves and marginal growth lines.

Figures g–h are of exterior surfaces of radials viewed in an inverted position. It is this surface that forms the inside of the craterlike hollow at the base.

Figure i shows the interior surface of a radial, the thick sutures where it meets the bibrachials and the larger interradials, and the narrowing at the suture to meet the smallest of the lower interradials.

Figures j–k are of radials seen from their edges; j has a vertical ridge on the interior surface for the attachment of viscera, this ridge is not present in i and k.

Figures l–n are of bibrachials; l shows two as they join each other, m shows the interior surface and the remarkable widening of the face of the suture, n shows the exterior surface, and a deltoid suture with its transverse respiratory grooves. The last plate is of a less common form, i. e. is more acute at the apex.

The plates figured show some marked variation but all are from the same locality as the more complete specimen. They are now in the New York State Museum.

PLATE 5

Blastoidocrinus carchariaedens Billings (sp.)

Page 97

Figures a–j are views of outer surfaces of deltoids of different ages; a–d show only vertical, foldlike ridges; f–j increasing differentiation of surface markings due to additional areas added at the border; in "i" the earlier deltoid has come to lie in a margin composed of apparent folds which lie at right angles to the lateral edges of the plate; in "j" these lateral ridges are even better developed.

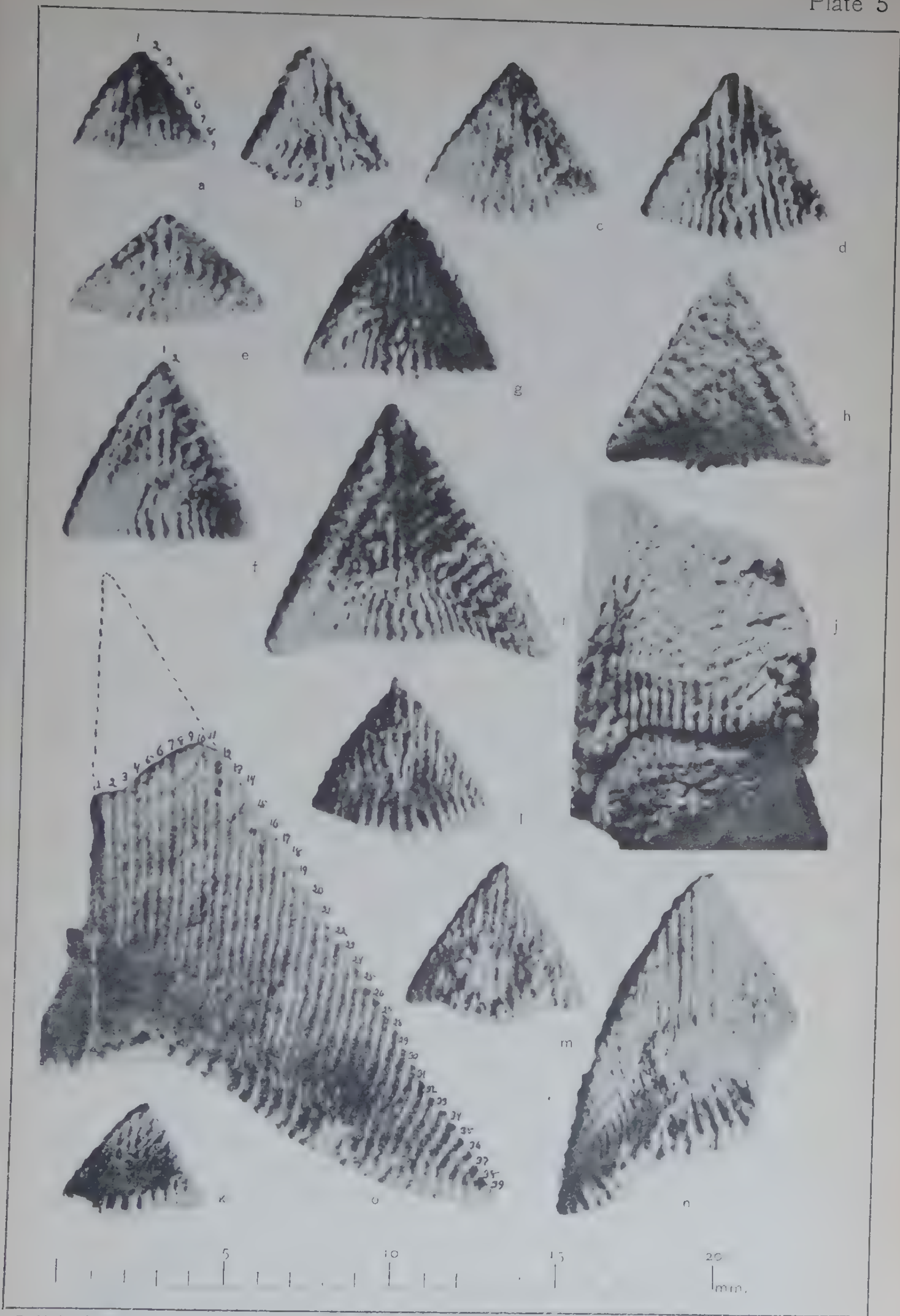
Figure h is unique in its surface markings and figure e in its angles.

Figure j shows clearly the incised hydrospire exits where the margin of the plate meets the displaced bibrachial. For the corresponding grooves on the bibrachial see the lower edge of figure n on plate 4.

Figures k–o show the inner surfaces of five plates of different ages. There has been no widening of the hydrospire grooves with age. Figure n shows traces of the thin sheets of the hydrospires themselves.

The specimen represented at j is the property of Mr Percy E. Raymond. The other specimens figured are now in the New York State Museum.

It may be noted that the hydrospire exits are less in number than the hydrospire folds that feed them. Two or three folds occasionally empty through one exit. There is evidence of partial or incipient anastomosis along the line of hydrospire origin.



G. H. Hudson, Photo.

PLATE 6

Blastoidocrinus carchariaedens Billings (sp.)

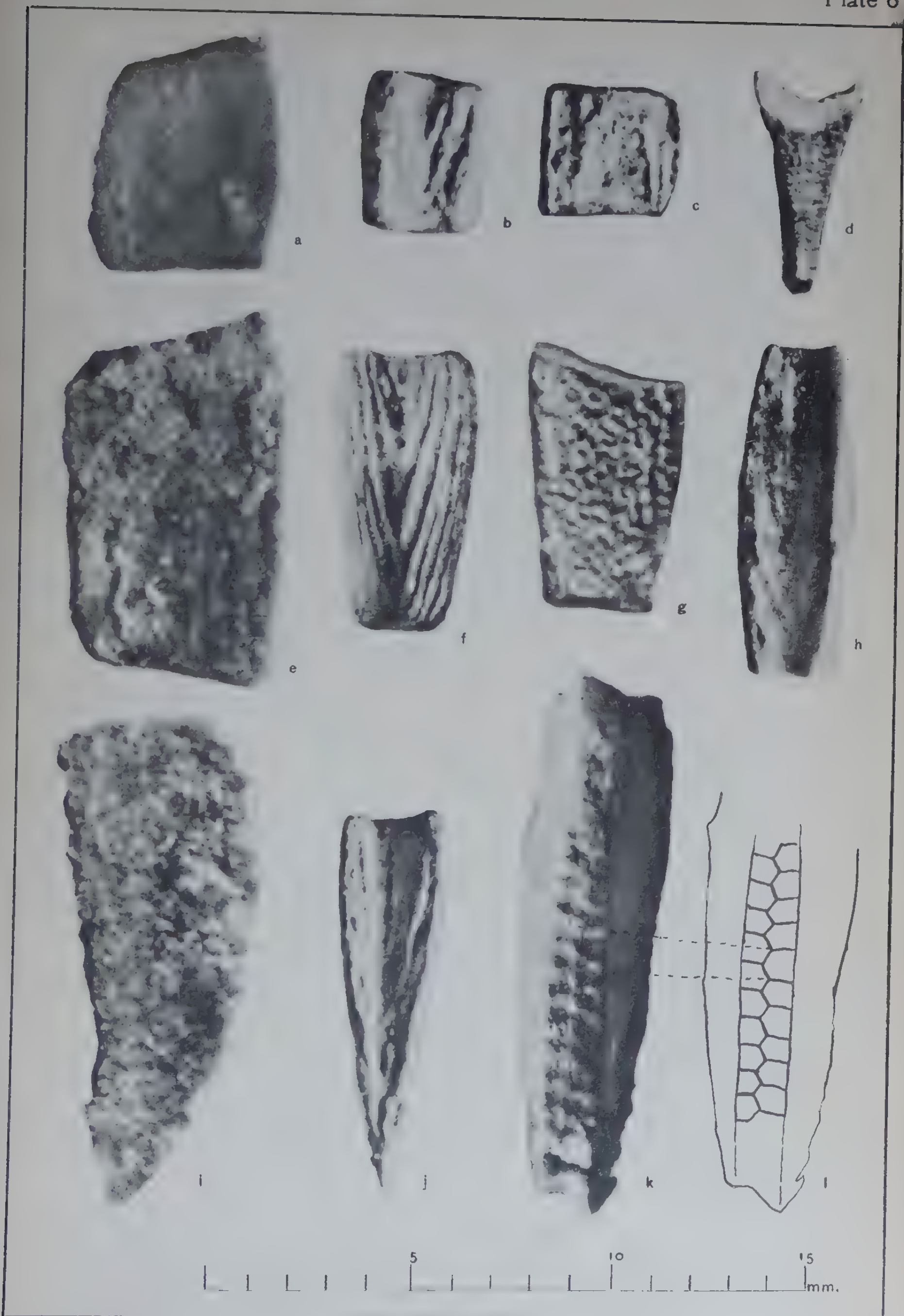
Page 97

Views of four different first wing plates are presented in figures a–d; of four second wing plates in figures e–h (though h may possibly represent a third wing plate); and views of three different third wing plates are given in figures l–k.

Figures a, e and i are of sides of plates, figure d shows the plate as viewed from one end, figure k from the inner edge and showing impressions of covering pieces which have been outlined in figure l, while the six remaining figures are of outer surfaces.

The ornamentation of f was produced by additions to the sides and to the lower end of the plate which were made successively after periods of rest. This marking has been more or less masked in the other plates figured. The third wing plate shown at k evidently did not terminate the line but must have been followed by a fourth.

These plates are now in the New York State Museum.



G. H. Hudson, Photo.

PLATE 7

Blastoidocrinus carchariaedens Billings (sp.)

Page 97

Figures a–o are of the under or inner surfaces of what the author has called apical or anal pieces. They show the gradual development of a depression (due to downward growth of the piece) which led Mr E. Billings to describe them as possessing a "central perforation." The oldest member of the series seems to clearly show the impression of five subtegmenal? plates of the peristome, the one in the lower interradius of the figure being displaced. Other figures, particularly l, show traces of the displaced plate and of the other plates.

Figures p, q and x are of outer surfaces. A four rayed piece is shown at g and a six rayed piece at x.

The remaining figures are of stem joints and of roots that may belong to this species.

The specimens figured are now in the New York State Museum.

G. H. Hudson, Photo.

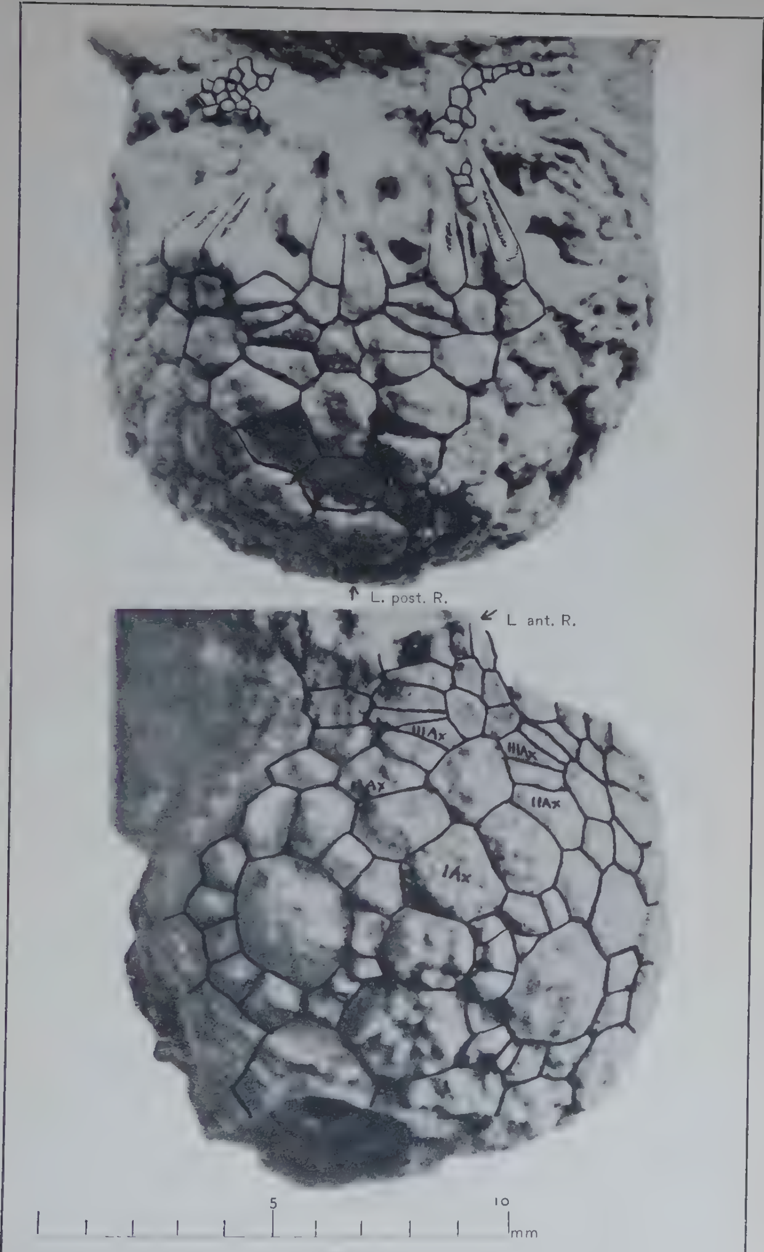
PLATE 8

Deocrinus asperatus Billings (sp.)

Page 122

Two views of the type of "Rhodocrinus" asperatus Billings. Most of the sutures and a few of the small plates of the tegmen were outlined on the photograph before reproduction.

The unique original is from the Chazy limestone and was found "in a quarry about 2 miles north of the city of Montreal." It is now in the Museum of the Geological Survey of Canada, at Ottawa.



G. H. Hudson, Photo.

PLATE 9

Hercocrinus elegans sp. nov.

Page 125

Two views of the only specimen found. The base has suffered some displacement and one side has been crushed in. Some of the filled in material between the plates of the base has been indicated by cross hatching.

The specimen is from the same horizon that yielded the Blastoidocrinus and is now in the collection of the writer.

G. H. Hudson, Photo.

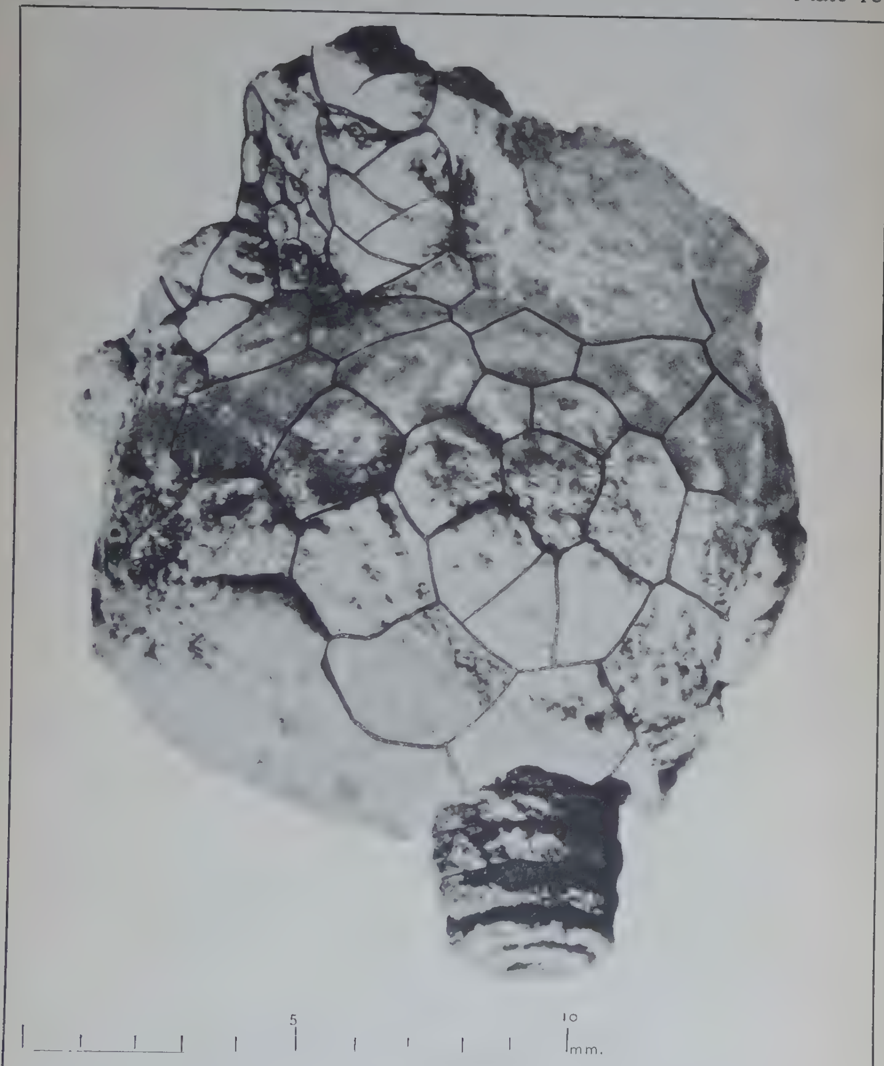
PLATE 10

Hercocrinus ornatus sp. nov.

Page 127

From a photograph of the only specimen found. A few sutures have been marked with ink to show them the more clearly.

The specimen is from the same horizon that yielded the Blastoidocrinus and is now in the collection of the writer.



G. H. Hudson, Photo.

SOME NEW DEVONIC FOSSILS

BY

JOHN M. CLARKE

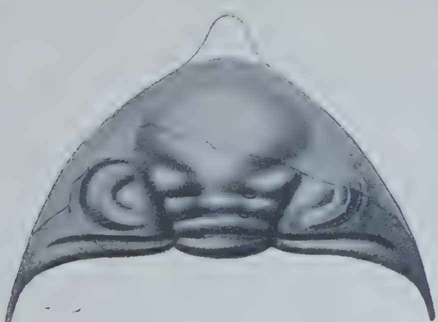
Introductory note

It is not a customary procedure of the writer to issue preliminary reports on investigations in progress, but to insure some part of the results of labors extending over several years, it seems well to make exception in the present case by publishing the following notes on some of the Devonic fossils that have come under consideration during this time. Fuller accounts and more elaborate illustration of them will follow in proper time and without undue delay. These species are from the representatives of the New York early Devonic formations in Gaspé, Province of Quebec; Dalhousie, Province of New Brunswick; eastern and central Maine. It may be added that they are the incidents of a somewhat protracted study of features in the *Early Devonic Stratigraphy and Physiography of Eastern North America* and all are believed to be new to science.

TRILOBITES

Dalmanites griffoni nov.

In lobation of tail there is little to distinguish this species from D. micrurus Green, and the general outline of the head and of



Dalmanites griffoni

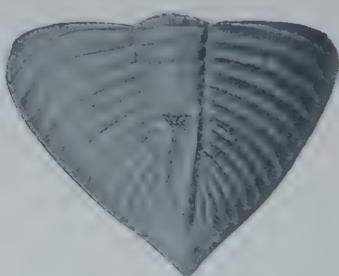
the glabellar lobes is similar, but in excavating these fossils from the compact residual clay into which the rock at the locality

indicated has altered I observed and made note of a cephalon on the anterior limb of which was a very pronounced elongate and spatulate extension, as is represented in outline in our figure. This was so fragile that I was unable to preserve it and no other specimen of the cephalon was complete in this frontal region. It is such a prolongation or snout as one sees in Salter's figure of D. longicaudatus [British Trilobites, 1864, pl. 3, fig. 19] from the Wenlock shale which one may regard as an incipient condition of the Probolium condition.

Lower Devonic. St Alban beds, Griffon Cove river, P. Q.

Dalmanites coxius nov.

This species is represented by a pygidium subequally triangular and distinctly flat with relatively narrow axis and broad sides. The margins have a slight outward curve and meet behind in a short broad caudal spine. The pleural ribs extend very nearly to



Dalmanites coxius

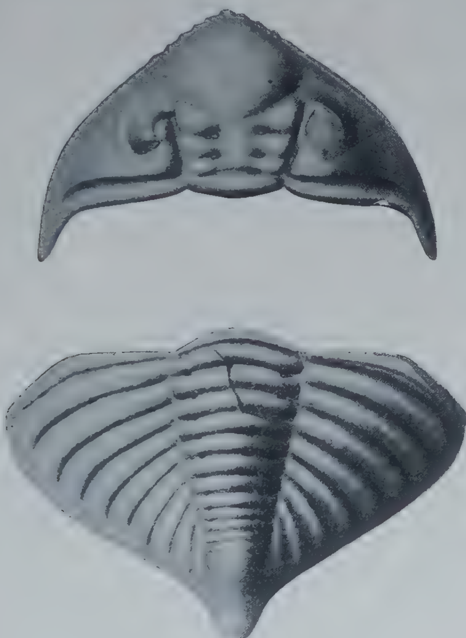
the margin and on the cast they appear to be elevated abruptly on the posterior edge and slope gradually from this edge upward. The same character is noticeable on the segments of the axis. The intervening grooves are thus not sharply defined except at their upper margins. There are 12 of these flattened shelving ribs on the pleura and 12 to 15 on the axis. Each of the pleural ribs shows trace of a fine surface groove. The test is very thin and its surface so far as known very finely granulated. The specimen has a length of 35 mm and a width of 44 mm. I should be at a loss for a known species with which to compare this tail. In respect to the character of its segments and its thin test it is like D.

limulurus, the well known Upper Siluric species of New York, but therein the resemblance ceases.

Lower Devonic. Probably from Cape Rosier, P. Q.

Dalmanites dolbeli nov.

Certain cephala and pygidia which there are good reasons for assigning to each other present many points of resemblance to several well known species of the same subgeneric type. The lat-



Dalmanites dolbeli

ter are D. pleuroptyx of the New Scotland beds (Helderbergian), D. stemmatus of the Oriskany and D. anchiops of the Schoharie grit. Generally speaking these four species are alike in the following respects: They are all forms which attain a large size, have notably short and broad cephala, with the first and second glabellar lobes fused distally and elevated to the eye lobe, frontal border with a row of crenulations at the edge, the more conspicuous being terminal, grooved eye base, faint if any groove along the lateral facial suture, and inosculating surface markings on the cheeks. The tails are broadly triangular and sparse ribbed ending in caudal spines not greatly extended.

By tabulating the differentials of these four species we shall indicate the features in which D. dolbeli is unlike the rest.

	pleuroptyx	stemmatus	anchiops	dolbeli
Cephalon	Short	Longer	Short	Short
Occipital ring	No spine	No spine	Spine	No spine
Confluent papillae on cheeks	Conspicuous	Inconspicuous	Inconspicuous	Inconspicuous
Suture line on cheek	Flush	Flush	Depressed	Flush
Pygidium Lateral ribs	11–13	9–10	8–9	8–9
Axial ribs	13–(15)	9–(11)	9–(14)	10–(13)
Ribs	Deeply grooved, rounded	Not grooved, rounded	Not grooved, rounded	Faintly grooved, rounded
Caudal spine	Short, acute, elevated axially	Broad, obtuse, not elevated axially	Slender, extended, upturned, not elevated axially	Broad, somewhat extended, upturned, blunt, and not elevated axially

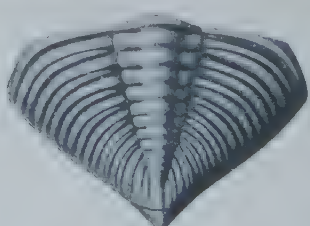
Sharing its principal structures with the other three and separated from them by differentials which are of the same quality as those distinguishing other members of the series, D. dolbeli represents a notably early Devonic type of structure.

Dimensions. Cephalon: large examples attain an axial length of 40 mm and a width of 75 mm. Pygidium: an average example has a length of 40 mm and a width of 60 mm.

Lower Devonic. Grande Grève and Shiphead, P. Q.

Dalmanites lowi nov.

A very distinct type of structure is presented by a few pygidia which are of considerable size, relatively quite short, broad at the



Dalmanites lowi

top, with pleural ribs 10 or 11 in number, the last three of which are simple and faint but all the rest very strongly duplicate throughout their entire extent becoming obsolete at or just within the margin. The axis is broad and the dorsal furrows rapidly approx-

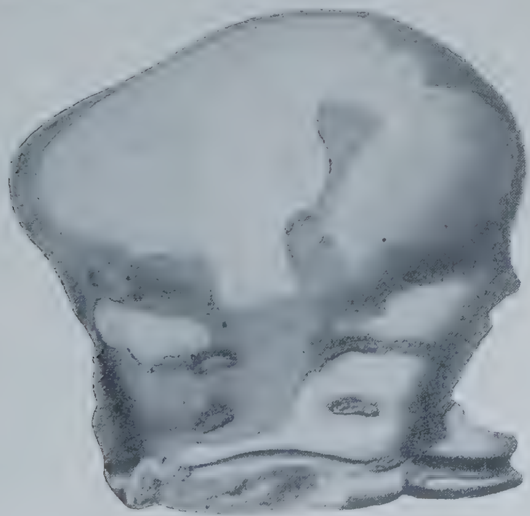
imate; it bears 11 or 12 segments and its apex is not abrupt but merges into a low median ridge continued to the end of the tail. The terminal spine is little more than a broad and short rather obtuse expansion. The surface of the test is finely granulate except for a few scattered coarser pustules on the axis. The specimens average 26 mm in length and 29 mm in width.

This style of pygidial structure with strongly bifurcate pleural ribs is represented in the faunas of the early Devonic elsewhere by such species as D. bisignatus Clarke (Oriskany) and D. dentatus Barrett (Oriskany). It is probable that the cephala of all have a crenulated or dentate border as D. dentatus and its associate D. dolphi Clarke are known to have.

Lower Devonic. Grande Grève and Indian Cove, P. Q.

Dalmanites perceensis nov.

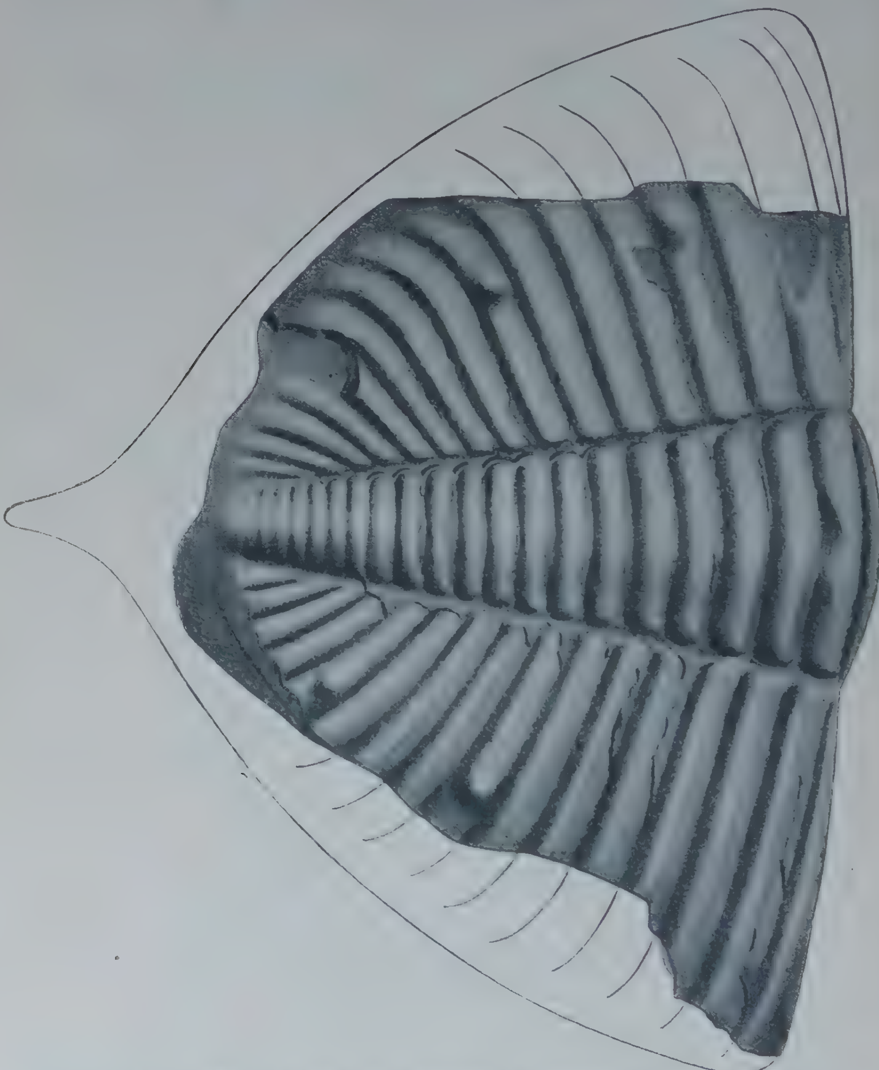
The parts found of this species are separated pygidia and cranidia. In the latter the frontal lobe is gently rounded and depressed; the first and second lateral lobes well fused at their extremities; the surface of the frontal lobe coarsely papillose. The



Dalmanites perceensis

pygidium is broadly triangular, but little arched at the sides; the lateral margins rounding in full curves and the tail spine short, acute and upturned; the axis has straight regularly converging dorsal furrows and its width is less than two thirds the width of each pleura. It bears 18-20 broad flat directly transverse annula-

tions with very narrow furrows. The fourth and eighth annulations bear two strong nodes on the axis and the 9th, 12th and 13th show fainter traces of them. The broad and flat pleurae bear 15-17 flat ribs grooved by narrow and sharply incised



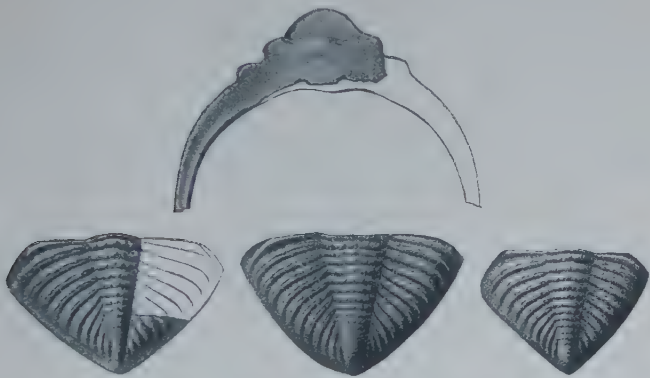
Dalmanites perceensis

oblique furrows; the ribs bend abruptly backward near the margin and are discernible almost to the edge of the shield. They are also sparsely but very irregularly nodose, the nodes being large and coarse. The whole surface is finely granular.

Lower Devonic. Percé rock, P. Q.

Dalmanites veiti nov.

Associated with specimens of D. phacoptyx from the limestone hills behind Peninsula, Gaspé Bay, are abundant pygidia and cephala of uniform size, unlike the species with which they are associated as well as with any others of our acquaintance. These pygidia are relatively small, subequally triangular, flattened above and rather abruptly sloping at the margins; apparently without tail spine. There are 11–12 lateral ribs, 6 or 7 of which are grooved medially. The axis bears 13–14 segments. The upper limb of each of the divided lateral ribs carries 2, 3 or 4 pustules so devel-



Dalmanites veiti. The underside of the cephalic doublure x2 and three pygidia natural size

oped as to overhang the sulcus, while each segment of the axis bears a single row of 5, 6 or 7 pustules. The length of these shields will average 23 mm with an anterior width of 29 mm.

The cephala belonging to these pygidia are not completely preserved but indicate a type of simple glabellar lobation as in D. micrurus, with closely pustulose surface. The border is smooth laterally but in front is extended into a short crenulated snout or shelf as in D. pleuroptyx and D. dolbeli though less expanded at the sides than in either of these.

There is undeniable similarity between this fossil and the D. bisignatus described by me from the Oriskany of Becraft mountain.[1] The latter, known only from the pygidium, has the part narrower and more elongate and its axial pustules are so arranged as to make a longitudinal median double row. That species we have noted (*op. cit.*) is allied to D. dentatus Barrett from the same horizon in Orange county, N. Y. but in ignorance of the cephalon of the

[1] N. Y. St. Mus. Mem., 3. p. 19, pl. 2, fig. 6–8.

former, comparison can go no farther. Dalmanites veiti has a type of cephalon quite unlike that of D. dentatus which is dentate on the entire periphery.

Locality. This species has been found only in a loose block from the limestone ridge behind Peninsula, Gaspé Basin, in association with D. phacoptyx, Phacops logani gaspensis, Platyceras conulus, Anoplia nucleata and other species of the Grande Grève fauna.

Lower Devonic. Grande Grève, P. Q.

Dalmanites whiteavesi nov.

This species is represented by a series of small pygidia somewhat of the type of that part in D. anchiops Green but more particularly like that of D. meeki, figures of which may be found in Walcott's *Palaeontology of the Eureka District,* 1884, pl. 17, fig. 5, and *Palaeontology of New York,* 1888, v. 7, pl. 11A, fig. 29, 30;

Dalmanites whiteavesi

that is, rather short and subtriangular but with rounded margins and an extended, slender caudal spine. The axis is moderately broad and convex bearing seven or eight segments which are well rounded and the pleural ribs are of the same number, flat on top with narrow intervals and each is grooved by a fine line.

The margins of the shield curve slightly outward uniting behind to form a spine which has about one fourth the length of the shield. It is narrow, ends acutely and is slightly upturned. As a whole the shield is shorter, relatively broader and has more segments than does D. meeki. The latter is from the lower part of the Devonic series in Nevada.

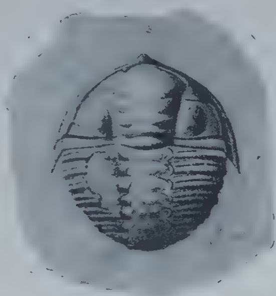
Lower Devonic. Grande Grève, P. Q.

Dalmanites gaveyi nov.

We are here presented with a species in which the frontal margin of the head bears a slight, simple, lobed and blunt extension without accessory processes or crenulations similar in effect to that of D. griffoni. This is a structure after the type of D. vigilans

Hall and D. limulurus Conrad of the Niagaran, of which a simple, well lobed structure of the glabella is an accompaniment.

This species has been observed in several examples, has a rather short cephalon in which the glabella is subpentagonal, the dorsal furrows not deep and rather obscure at the outer ends, the frontal lobe highly transverse, right short, and merging directly into the frontal extension. The glabellar furrows are very obscure, the first and second lobes but ill defined, slightly swollen and club-shaped but the third lobes are linear and are better defined. Eyes



Dalmanites gaveyi

comparatively small and not sulcate at the base, cheek spines very narrow and produced. The cheeks slope somewhat abruptly to a thickened and rounded edge without border. The surface is marked by no noticeable pustules but by a fine granular ornament. This is a very distinctive and rather rare type of structure expressed not so much in the frontal projection as in the somewhat swollen aspect of the glabellar lobes and the obsolescence of the furrows, as well as the smoothness of the surface.

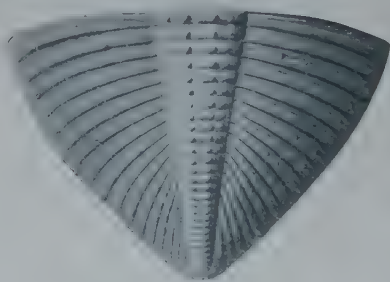
Dimensions. Length 12 mm, width 23 mm. One of the specimens carries a considerable part of the thorax but the pygidium of this species is not yet identified.

Lower Devonic. Grande Grève, P. Q.

Dalmanites ploratus nov.

There is a group of tuberculated dalmanites in the early Devonic rocks, embracing D. dentatus Barrett (which the ornament of the cephalon shows to be a Corycephalus), from the Port Jervis Oriskany, the allied D. bisignatus Clarke and D. phacoptyx H. and C. from the Becraft mountain Oriskany. Of the last two the pygidium of the former is a shield of slender propor-

tions with regularly widened tubercles on the axis, in the other it is large and has coarse irregularly scattered tubercles. The pygidium before us is of the general type of D. bisignatus but is larger and considerably more segmented. Thus D. bisignatus has 7-8 pleural ribs while D. ploratus has 15-16, the former 10-12 axial rings, the latter 20-22. Notwithstanding this difference there is a similarity in the size and arrangement of the tubercles or



Dalmanites ploratus

granules; on the annulations there is a single row of four of which the middle ones are largest. Passing to the apex of the spindle this middle pair becomes more conspicuous by the disappearance of the others and thus there appears to be a double axial row of these pustules. On the pleurae they are scattered irregularly and faintly over the sulcate ribs. Our specimens do not show whether or not the caudal extremity ends in a spine.

Lower Devonic. Loose at Cunningham's camp, 4 miles below Matagamon lake, Me.

Dalmanites (Probolium) biardi nov.

Phacops weaveri? Salter. Silurian Trilobites. 1864. p. 57, fig. 15

Cephalon broadly subelliptical in outline, short axially, like the prevailing type in contemporaneous faunas (D. anchiops, pleuroptyx, stemmatus, nasutus, tridens). Glabellar division normal but the usual fusion of lobes 1 and 2 at their distal extremities which affects so many of the early Devonic species of Dalmanites, is not strongly expressed and herein again there is agreement with D. (Probolium) nasutus and tridens. Margin entire except near the anterior extremity where there is a series of broad low scallops or crenulations, three or four in number on each side of the snout. These are so obscure

that they are seldom seen except on casts of the ventral surface of the border and in such cases the outermost sometimes assume the aspect of a pair of subsidiary spines. The snout is axial, has a broad base, is contracted in diameter medially and at the distal extremity carries a trident the central process being axial, the other two diverging palmately and all considerably extended. There seems to be some variation in the length of this process but apparently it was from one third to one half as long as the cephalon itself. The entire process is flat. In the trilobed species of the

Dalmanites (Probolium) biardi

New Scotland beds, D. tridens, there is likewise noticeable variation in respect to the development of these processes as shown by the figures given in *Palaeontology of New York*, v. 3, 1859, pl. 75, fig. 3–6; it sometimes has them so much reduced that the extremity takes on a spatulate outline. The genal spines are relatively broad and short. The surface of the cheek below the visual area is deeply grooved, the facial suture on the cheeks does not lie in a furrow and the surface below the eyes shows only rather obscure traces of confluent papillae. The general surface

is rather finely pustulose especially on the cheek spines. The thoracic segments show no features that can be regarded as distinctive.

Pygidium. Elongate, subequally triangular, subacuminate, of the general type of D. m i c r u r u s and less like the nodose surface with long tail spine characterizing D. (P r o b o l i u m) n a s u t u s. Axis relatively narrow, segments 10 to 12. Pleural ribs 9 to 10, flat above, grooved by a fine line and separated from each other by rather narrow furrows. Caudal termination a broad and short, acute and slightly upturned spine. Surface finely granulose on the ribs and along the margins with obscure evidence of low faint nodes.

Dimensions. The average of our specimens indicates a length of cephalon not including the snout, of 30 mm, a width of 63 mm. In such a specimen the snout would have a length of 16 mm with a spread from tip to tip of the lateral spines of 12 mm. An average pygidium measures 36 mm in length and 42 mm in width.

Lower Devonic. Percé rock and Blowhole cliffs, P. Q

Dalmanites (Probolium) esnoufi nov.

A quite imperfect cephalon in general features has the aspect of the shields referred to D. m i c r u r u s Green, the border being broad, flat and smooth at the edge, the frontal lobe of the glabella transverse and rather narrow, the other lobes quite small but the

Dalmanites (Probolium) esnoufi

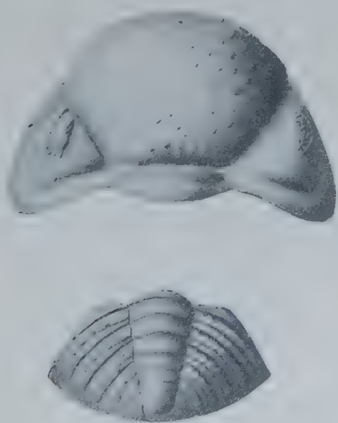
first two lobes are fused at the outer edges. The genal spines are produced, the eyes furrowed at their base and the groove within the border is conspicuous. The border in front is produced into a bifurcate process, the branches of which are flat, very divergent and rise from a broad base.

The aspect of the cephalon before us is very unlike that of D. (P.) biardi in the various details referred to. Dalmanites (P.) nasutus Conrad[1] is a bifurcate species in the Helderbergian (New Scotland beds) of New York, which has more in common with P. esnoufi, specially in its smooth border, but the base of its snout is very much more elongated and its branches slender and cylindrical. The specimen measures in length, from tip of snout 32 mm, from front of glabella 23 mm and in width 50 mm.

Lower Devonic. Grande Grève, P. Q.

Phacops logani Hall var. **gaspensis** nov.

The species of Phacops very common in the Grande Grève limestones presents itself in all variations of size. The larger forms are coarsely tubercled on the glabella and in these there is a well defined row of knobs on the thoracic axis along the dorsal furrows, shown always to best advantage on the internal cast. The pygidium



Phacops logani var. gaspensis

has four to five duplicate lateral ribs. Added to these critical features is the absence of genal spinules. The larger of these forms have a close and distinct resemblance to the species described by Hall as P. bombifrons[2] from "the limestone of the Helderberg mountains," by which was intended that now known as the Onondaga limestone, a resemblance expressed in all the characters of the cephalon which carries a full bombate glabella. We have

[1]Palaeontology of New York, 3: 362, pl. 76, fig. 1–8.
[2]Descriptions of New Species of Fossils. 1861. p. 67; N. Y. State Cab. Nat. Hist. 15th An. Rep't. 1862. p. 95; Illustrations of Devonian Fossils. 1876. pl. 6, fig. 22–24, 29.

no means of knowing the other parts of the animals thus designated by Hall. In the Grande Grève rocks these large, coarsely tubercled cephala have the thoracic segments knotted at the dorsal furrows as in large specimens of Ph. logani. In smaller specimens these thoracic characters are obscured except in the cast, but the cephalic shields of the latter do not show the spinules of the Percé species and of typical P. logani.

The variations of expression in the representatives of the genus Phacops in the New York Devonic are slender and identifications are always obscure. Fixing upon the following characters as critical, viz, the cristation of the genal angles, the knotting of the thoracic segments and the grooving of the pleural ribs on the pygidium, we may tabulate the species thus:

	Cheeks	*Thorax*	*Pygidial ribs*
P. logani (Helderbergian)	faintly spined	knotted	duplicate
P. cristatus (Schoharie grit)	strongly spined	smooth	duplicate
P. cristata var. pipa (Onondaga)	faintly spined	smooth	duplicate
P. bombifrons (Onondaga)	smooth	smooth	duplicate
P. rana (Hamilton-Ithaca)	smooth	smooth	simple

In this schedule the Grande Grève species takes a place close to P. logani; the Percé form, which is always small, is a near approach to the typical expression of the species.

Lower Devonic. Everywhere along the Florillon from Shiphead to Little Gaspé, and in the blocks of limestone from the second range found in the stream bed at Peninsula. Also at the Ruisseau du Grande Cavée associated with Dalmanites griffoni, and in Percé rock, P. Q.

Phacops (Phacopidella) nylanderi nov.

This is an addition to the peculiar group of early Devonic species of which we recognize the following other members: P. brasiliensis (Maecurú), P. anceps (Decewville), P. correlator,

Phacops (Phacopidella) nylanderi

New York Oriskany and Gaspé sandstone. We have noted in what respects this group departs from the structure presented by P. downingiae, the exemplar of the generic group Acaste=Pha-

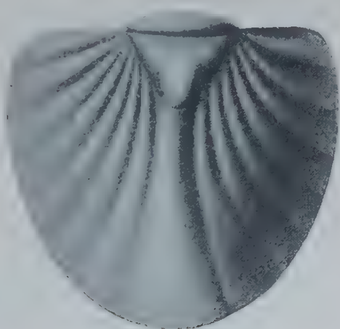
copidella Reed. The material from this locality has afforded but a single cephalon of small size with semicircular outline, rotund but not protuberant glabella, in which all glabellar lobes are extinct save that at the base which takes the form of a narrow and obscure ring. The preservation here is without compression which in some of the other species of the series serves to indicate the glabellar furrows. The nuchal ring is elevated, the eyes relatively large, and the small cheeks are apparently produced into short genal spines. The length of this specimen is 4 mm and its full width 8 mm.

No indications of other parts that can be referred to this species are present.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Bronteus barrandii Hall var. **majus** nov.

A pygidium with the structural details of B. barrandii, but having many times the size distinctive of that species in New York and Gaspé. It has the short axis, broad median rib and



Bronteus barrandii Hall var. majus

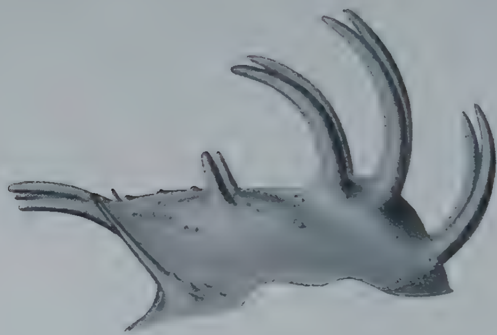
seven lateral ribs on each side, all becoming obsolete on the smooth border. There is here no variation from the specific type but a noteworthy distinction in expression.

Lower Devonic. Stewart's cove, Dalhousie, N. B.

Lichas (Gaspelichas) forillonia nov.

The several parts of this species found are, on account of the great spines, intricately complicated with the matrix and it has been possible to extricate them only at the cost of infinite labor and

patience. The species is not common and our specimens represent three cranidia with separated cheeks. The general type of cephalic structure irrespective of the spines is practically that normal to such typical expressions of Lichas as seen in Arges, Ceratolichas,



Lichas (Gaspelichas) forillonia

Hoplolichas and Conolichas, the frontal lobe being large, ovoid and prominent, not set off by deep lateral grooves as in Terataspis but most prominently elevated posteriorly. The lateral lobes are long and narrow, subcrescentic in form and but very slightly elevated so that the surface between the dorsal furrows is low, gently

convex and very long, terminating posteriorly in a more elevated triangular area. The prevailing aspect of the cranidium and glabellar lobes is that of narrowness and length, particularly in the distance between the nuchal furrow and the frontal lobe. The nuchal furrow is broad and low and the occipital ring broad, flat and arched.

Spines. While the general surface is tubercled and some of the tubercles become developed into short spines the major spines are as follows: three pairs, one in front of another on the crest of the glabella; these are of great size and strength and deeply curved backward. They seem to be all of about the same length. In some of our specimens the posterior pair curves backward in a long arch to and beyond the posterior margin of the head, but in a younger specimen they are shorter. The middle and anterior pairs are quite as long. In section these great frontal spines or hooks are not circular but somewhat flattened on the opposing faces though rounder on the outer surface and narrow fore and aft.

On each lateral lobe where widest, and just above the dorsal furrows, is a spine of less hight than the foregoing and apparently erect and these are flanked in front by a much shorter pair. These five pairs seem to be all there are on the glabella except for the spinous tubercles in the occipital area.

The occipital ring bears at its edge on the axis a series of long curved flat or vertically compressed spines, one at the middle and one diverging from the axial spine, at each side. These are neither as long nor as large as those of the frontal lobe but they must have reached back over several of the thoracic segments. The occipital ring is deeply contracted at the dorsal furrows and where it expands again beneath the cheeks it extends out on each side, into a flat but straight and slender spine larger than the others. This makes five spines on the neck ring, 15 in all on the cranidium, seven pairs and one axial. It would be natural to expect others on the palpebral lobe but these seem to be wanting.

The other parts of the species are represented by portions of free cheeks which indicate that these ran out into short, thick and narrow genal extensions with a row of rather small spines along the occipital margin, while just outside of the eye near the margin there was a very large, long and recurved hook like those of the frontal lobe. There is still some uncertainty as to the exact details

of these parts, due in large measure to the difficulty of extracting them from the rock.

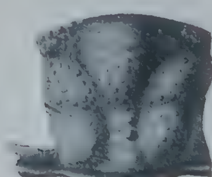
Dimensions. The largest of the specimens affords the following measurements: Probable entire length to top of axial spine, 90 mm; length of posterior glabellar spine (not restored) 41 mm; on the curve, 55 mm; greatest vertical hight of anterior spines (not restored) 30 mm; length of lateral occipital spines, 27 mm; vertical hight of spine on cheek, 30 mm. These figures indicate that the species is one of the largest as well as the most extravagantly ornamented of all forms of Lichas. It is surpassed in dimensions only by Terataspis grandis and Uralichas ribeiroi, the lords of this tribe. Equipped with cerements of mortality, successors of this genus Gaspelichas are not to be expected.

Lower Devonic. Grande Grève, P. Q.

Lichas bellamicus nov.

This is a species of medium dimensions having the lobation of cephalon and the outline of the pygidium very similar to the corresponding parts in the prevalent forms of Lichas from the Helderbergian.

The frontal lobe is pyriform, not elevated or bombate but uniformly convex, without abrupt posterior slope; the lateral furrows



Lichas bellamicus

are deep and the converging lateral lobes elongate, of about equal width throughout and divided only by an extremely faint cross furrow. The grooves dividing these outer glabellar lobes forming the fixed cheeks are very shallow, and these cheeks are convex and elongated about the eye lobes. The cephalon appears to be bounded by a smooth margin which is flat in front. The entire surface except the furrows is coarsely tubercled and it would

appear that some of the tubercles at the crest of the frontal lobe are extended into thick spinules. Parts of a pygidium indicate that this organ was flat and extended and the margin carried long flat spines.

Lower Devonic. Grande Grève, P. Q.

Ceratocephala robinia nov.

This form is known from various parts and one nearly entire specimen, which attains much larger proportions than C. tuberculata (Helderbergian) and yet is allied to both that species and the C. callicephala from the Onondaga limestone. Placing these species in comparison we may find the distinctive characters expressed as follows:

Ceratocephala robinia

	C. tuberculata	C. callicephala	C. robinia
Size	Small	Medium	Large
Neck ring	With short stout spine	With small spine	With longer, stout and somewhat curved spine
Thoracic segments	Finely tubercled	Regularly and coarsely tubercled	Coarsely tubercled
Pygidium 1st spines	Moderately long	Slender and longer than 2d pair	Very short
2d spines	Much longer	Shorter than 1st pair	Longer than 1st pair
3d spines	Large, stout and twice the length of 2d pair	Not conspicuously the largest of the series.	Sharp and slender, longest
4th spines	Very short	Relatively long and slender	Sharp and slender, more than ½ the length of 3d pair
Surface	Strongly tubercled	Tubercled	No tubercles

These differences will be found to pertain chiefly to minor features but we conclude that there is in the Gaspé specimens a distinction from these allies in time and structure which is clearly defined and significant in the interpretation of these faunas. It is not at present possible to say whether the New York Oriskany species is of the same type.

Dimensions. The only specimen which we have observed having the parts together is in the Redpath Museum of McGill University. We owe to Prof. F. D. Adams the opportunity of studying this example. It is from Grande Grève and has a length of 20 mm. Cranidia of other specimens are of about the same size.

Lower Devonic. Grande Grève and Percé rock, P. Q.

Cordania gasepiou nov.

Body small, oval, cephalon with ovoid coarsely tubercled glabella and small basal lobes, small and highly elevated eyes beneath which the cheeks are excavated and concave and the anterior limb also concave and broad, bordered by an upturned thickened rim; genal

Cordania gasepiou

angles extended into slender spines reaching more than two thirds the length of the thorax. There may be a spinate tubercle on the neck ring but this has not been fully determined. The thorax has segments which are crested in the axial line by a row of spinules apparently increasing somewhat in length posteriorly and the lateral moieties of the segments are finely pustulose. The pygidium has

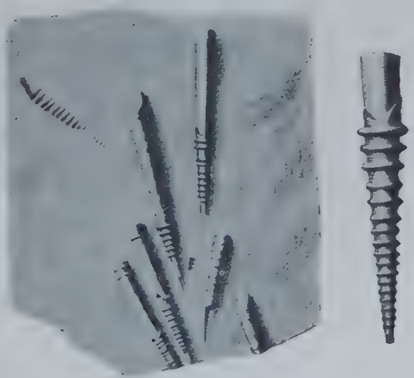
a strongly elevated axis and the median spines are higher and more recurved than those of the thorax. The pleurae are depressed convex and about the margin concave without a marginal rim. The pleural ribs are distinctly duplicate and equally so near the margin. All the pygidial ribs carry fine tubercles. The length of an entire specimen is 11 mm, width 9 mm.

Lower Devonic. Lehuquet's Cove, The Forillon, P. Q.

ANNELIDS

Tentaculites leclercqia nov.

Shells having very much the configuration of T. gyracanthus Eaton,[1] occurring, like that, in aggregations in the limestone, but uniformly of very much greater size. The slender cones, attaining a length of 10–15 mm, are strongly annulated but the



Tentaculites leclercqia.
The slab x2: the individual x5

annuli are often highly irregular in size and have an abrupt or concave slope on the lower side and a convex slope above. They are themselves covered with fine concentric elevated lines. The annuli appear to extend to the tip of the shell.

Lower Devonic. Percé rock, P. Q.

---

[1] See Hall. Pal. of N. Y. 1859. 3:137, pl. 6, fig. 22, 23 (T. irregularis); and *idem*. 1888. v. 7, suppl. pl. 104, fig. 7–13.

Tentaculites cartieri nov.

This is a large species with regularly annulated growth in early stages only but with increase in size the annulations become variable and of obscure outline, all the surface annulations and furrows alike being crossed by very fine regular and equal concentric lines, so that in respect to compression it is not remote from the Oriskany

Tentaculites cartieri
The larger x2; the smaller, x3

species T. elongatus. The internal cast bears the usual conformation, suggesting a series of inverted and insheathed cones.

These shells attain a length of 35–40 mm with an apertural width of 4 mm.

Middle Devonic. Gaspé Basin, P. Q.

Tentaculites scalaris Schlotheim

Tentaculites scalaris Schlotheim. Petrefaktenkunde, p. 377, pl. 20, fig. 8, 9; *et auctorum*

There are no evidences of distinction between specimens of Tentaculites found in the Chapman Plantation and this well known Coblentzian species. Our specimens bear the strong rounded

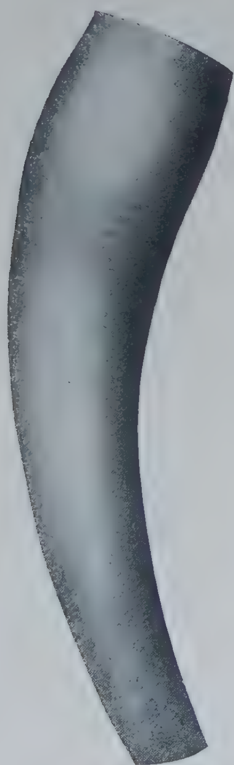
annulations, subject to very slight variation with some irregularity in the intervals and these annulations are covered with fine concentric lines.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

CEPHALOPODS

Cyrtoceras albani nov.

This quite common shell has a long slender and gently curved cone, broadly swollen on the body chamber and constricted behind



Cyrtoceras albani

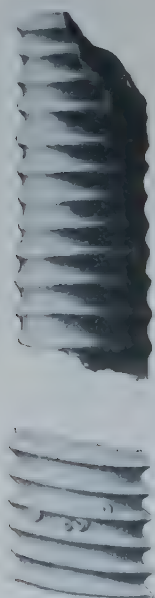
the aperture. The greatest curvature is in the later parts of the shell, the earlier portion being quite straight for a short distance.

The septa are regularly concave and close together, the surface ornamented by very fine elevated threadlike eccentric lines. The species is not unlike the C. subrectum Hall of the Helderbergian, whatever generic form that may prove to be when better known.

Lower Devonic. St Alban beds, Cape Rosier Cove, P. Q.

Kionoceras rhysum nov.

Straight longicones with regular narrow, erect annulations which may be slightly oblique and are separated by broad, smooth, con-



Kionoceras rhysum

cave or flat interspaces. On the best preserved external casts there is no trace of either longitudinal or concentric lines but the summits of the annuli are dotted or punctured.

This form is represented by specimens for the most part small, in which there are on the average six annuli in a length of 20 mm

but other examples indicate that the species attained large proportions.

Lower Devonic. Grande Grève, P. Q.

Kionoceras champlaini nov.

This species is represented by large cones having a series of low and broad undulations of the surface continuing quite to the aperture and these are crossed longitudinally by elevated, distant, simple

Kionoceras champlaini

lines with broad flat interspaces, each about 25 in number, the former becoming obsolete at the aperture.

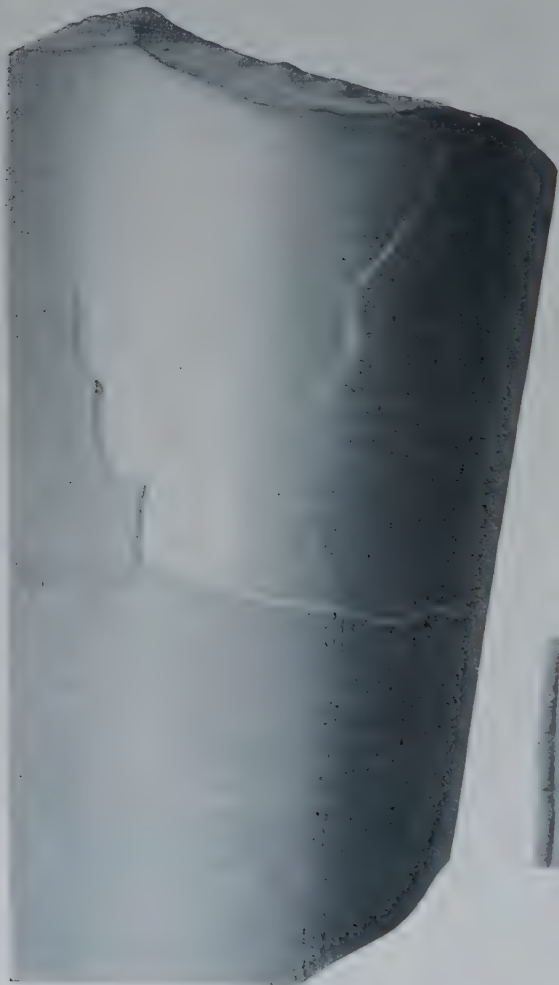
This species is of rare occurrence and its characters distinctive. The best preserved specimen has a width of 22 mm at the aperture and a length (incomplete) of 50 mm.

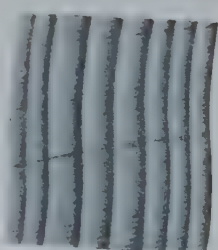
Lower Devonic. Grande Grève, P. Q.

Orthoceras norumbegae nov.

A robust shell of which we have about six inches of the final part, retaining the surface sculpture. The shell seems to have tapered gradually and to possess a circular section. The fragment at hand has a length of 165 mm, a width at the top of 75 mm, at the bottom of 60 mm. The sculpture

consists of incised vertical lines at irregular intervals, making very flat and low elevated striae; some broad, some very narrow and threadlike, all rather wavy and irregular in their course, large and





Orthoceras norumbegae

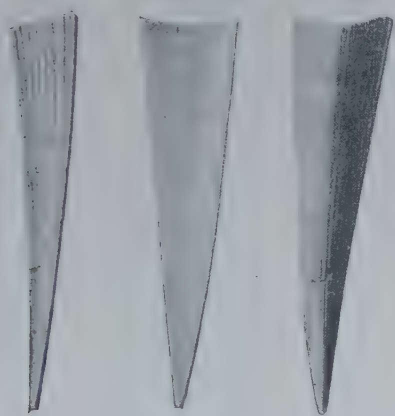
small interspaced without order. At wider intervals are deeper longitudinal sulci. All are crossed by faint and irregularly distributed concentric lines. This style of exterior is highly unusual and quite peculiar.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

PTEROPODS

Hyolithus richardi nov.

Shell large, tapering gradually; ventral face flat or slightly concave; dorsal face highly arched, subcarinate axially; apertural margin not produced on either face. Semioval in transverse section, apertural diameter to length as 1 to 3.5. The shell is slightly arched axially, the margins and the dorsal face being correspondingly incurved. The ventral surface is marked by very fine lines



Hyolithus richardi

concentric to the slightly reentrant curvature of the margin; these are not crossed by vertical lines except those of structure, but the axial area may be flat and its boundaries present the aspect of vertical lines or depressions.

The opposite or arched surface bears a series of rather coarse subequal vertical ridges separated by flat and broader intervals. Near each margin is a deeper groove; obscure concentric striae are also preserved on this surface. The apertural margin of this face is slightly inflected.

Length of average specimen 35 mm; apertural diameter 8 mm.

Lower Devonic. Grande Grève, P. Q.

Hyolithus oxys nov.

Shell usually larger than the foregoing and relatively much broader, margins tapering more rapidly, surface slightly arched axially. Ventral face gently convex throughout and produced at the margin beyond the opposite face into a semielliptical extension; dorsal face convex but much less so than in H. richardi, the

median portion the most elevated and bounded by two longitudinal grooves. Apertural diameter to length of ventral face as 1 to 2.5; of dorsal face as 1 to 2. The surface is marked only by concen-

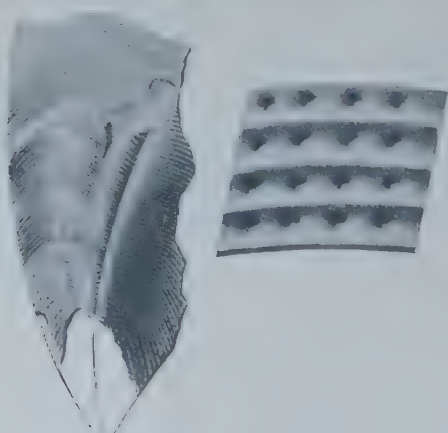
Hyolithus oxys

tric striae, arched upward on the dorsal face to correspond with the curvature of the margin; transverse on the ventral face. Average specimens measure 40 mm in length and 14 mm in apertural diameter.

Lower Devonic. Grande Grève, P. Q.

Conularia penouili nov.

A large species distinctly grooved at the angles and ridged at the middle of each face. The concentric markings are elevated



Conularia penouili

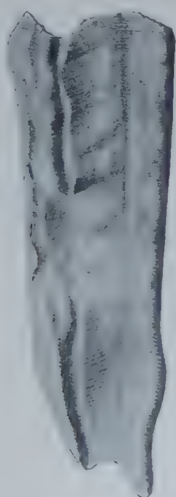
lines close together and curving broadly upward. These are smooth on the edge, without ornament, but the interspaces have

sculpturing consisting of a series of low subcircular depressions in transverse rows separated by elevated surfaces which may take on the form of short convex pillars. This ornament is only about the middle of each face; toward the edges it fades away or is replaced by fine longitudinal puckers starting with the upper slope of a transverse ridge and passing down the slope and part way across the interspace.

Lower Devonic. Loose at Peninsula, P. Q.

Conularia desiderata Hall var. **tuzoi** nov.

This is a large shell having the surface characters similar to those of C. desiderata, that is, consisting of fine transverse



Conularia desiderata var. tuzoi

lines bending backward at the center and bearing extremely obscure tubercles visible only when the preservation is exceptional. Unlike C. desiderata the shells bear evidence of a faint median vertical but not interrupting line on each face.

Lower Devonic. Percé rock, P. Q.

GASTROPODS

Platyceras leboutillieri nov.

Shell small, erect, apex minute not exsert; minutely coiled for one and one third volution, then abruptly expanded with a spiral twist, the body whorl being erect and subcylindrical and the total

volutions less than two. There is no evidence of spirality in the body whorl beyond the first third of the shell. Section of body whorl

Platyceras leboutillieri

circular. Shell growth somewhat irregular in late stages but apparently without nodes.

Aperture but slightly undulated.

Hight from apex to stoma 18 mm, diameter of body whorl near aperture 14 mm.

Lower Devonic. Grande Grève and Percé rock, P. Q.

Platyceras gaspense nov.

A rather small species with small spiral of one and one half whorls very rapidly expanding so that at the end of the one and one half volutions the shell is of notable width; thence the whorl becoming free

Platyceras gaspense

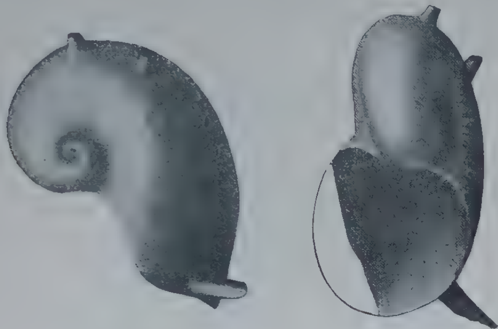
and suberect, suggesting the outline of P. thetis Hall of the Hamilton shales but with shorter body whorl and larger spire. The final whorl is compressed but appears to have been subelliptical in cross-section. Surface smooth with one or more longitudinal furrows.

Middle Devonic. Gaspé Basin, P. Q.

Platyceras paxillifer nov.

A small shell closely coiled for two and one half volutions or throughout its length, rapidly expanding and having the general aspect of a shallow Diaphorostoma or Strophostylus; the surface roughly corrugated concentrically, the upper shoulder of the shell bearing a single row of slender spines, beginning, in the best preserved specimens, at the end of the second whorl or the commencement of rapid expansion, and three in number at unequal intervals. This species represents one of the large group of spined Platycerata so frequent at this period in the development of the genus;

though none of this type has been described from the Helderbergian fauna yet representatives are known to occur therein, and in the Oriskany of Glenerie we have the multispinous shell P.



Platyceras paxillifer

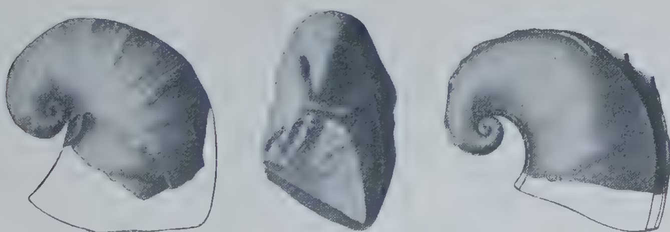
nodosum Conrad and P. subnodosum Hall, which usually appear in the form of nodate casts.

In the Onondaga limestone fauna are P. dumosum, echinatum, multispinosum, fornicatum but among them all is none of the type expressed in P. paxillifer.

Lower Devonic. Grande Grève, P. Q.

Platyceras guesnini nov.

Shell of medium size, suberect, subsymmetrically coiled; apex deeply coiled in horizontal plane, rapid expansion beginning at one and one half volutions, body whorl irregularly expanded, subcircular in cross-section, direct and unattached for one half its



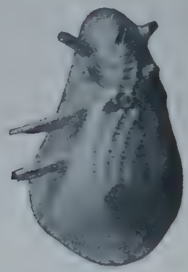
Platyceras guesnini

length. Surface without revolving furrows and ridges, and marked with subequidistant concentric undulating fringes gradually becoming obsolete near the aperture; also traversed longitudinally by very fine revolving lines.

Lower Devonic. Percé rock, P. Q.

Platyceras lejeunii nov.

Shell of medium size with relatively small coil and rapidly expanding suberect body whorl. Surface with subspiral or somewhat twisted longitudinal ridges crossing and festooning irregular



Platyceras lejeunii

concentric growth lines. The surface is covered with very long and slender spines which are curved or arched backward. The shell is more slender than other echinate species and the spines relatively longer and more arched.

Lower Devonic. Grande Grève, P. Q.

Platyceras (Orthonychia) belli nov.

Shell erect, minutely arched and incurved at the apex, expanding very gradually but equally for nearly one half its length and thence more abruptly, the cross-section of the whorls being es-

Platyceras (Orthonychia) belli

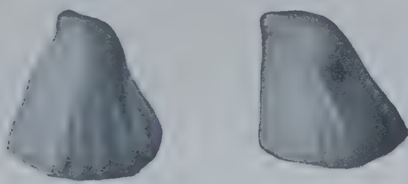
sentially circular and the stomal margin undulated. Surface crossed transversely by rugose concentric growth lines, their undulations corresponding to low grooves and folds of the shell. Length of a full-sized specimen 50 mm; stomal width 33 mm.

Lower Devonic. Grande Grève, P. Q.

Platyceras hebes nov.

Shell conical, slightly oblique, apex blunt or minute, surface expanding rapidly with a vertical slope on the posterior and a more broadly curved slope on the anterior side; lower part of the cone obscurely plicated, aperture nearly round.

This singular expression of Platyceras, noteworthy for its broad blunt apex, is quite unusual if not altogether new to American



Platyceras hebes

faunas, but such a shell has been noticed by Oehlert in the Lower Devonic of Augen and figured in the *Bulletin de la Socièté Gèologique de France*, 1890, volume 17, plate 19, figure 4.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Platyceras kahlebergensis Beushausen

Capulus kahlebergensis Beushausen. Abhandl. zur geolog. Specialk. Preussen. 1884. pl. 1, fig. 14

There seems no doubt of identity in this case. The species is a Platyceras with a Diaphorostomalike spire from which the body

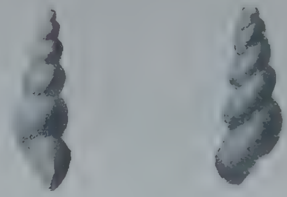
Platyceras kahlebergensis

whorl expands rapidly and carries a deep revolving sulcus on the lower side.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me., and in the Spiriferensandstein of the Hartz mountains at the Kahleberg.

Loxonema sp. cf. **funatum** A. Roemer

A shell of relatively rare occurrence with very faint sinuous ridges on the internal cast. It suggests the species referred



Loxonema cf. funatum

to from the Spiriferensandstein of the Hartz mountains.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Holopea gaspesia nov.

Shell rather small. Spire short, whorls three to four, somewhat flattened beneath. Expansion rapid, sutures sharp but not deep though the sutural region may be flattened; nonumbilicate. Stoma subcircular. Surface with fine and close concentric lines which about the sutures are gathered into coarse raised radii which are lost before traversing one half the whorl. Some specimens

Holopea gaspesia

show a series of two or more revolving raised lines on the body at and below the periphery and two of these may be the boundaries of a slit band, though this feature can not be determined from the sandstone casts. This, however, does not appear to be a prevalent character of the species.

Dimensions. An average specimen has a hight of 10 mm and a basal diameter of 9 mm.

Middle Devonic. Gaspé Basin, P. Q.

Holopea wakehami nov.

Shell small, compact, with depressed spire, full ventricose body whorl and small obscure earlier whorls, suture impressed, hight

to width as four to three. Aperture broadly oval, entire; inner lip thickened and slightly excavated. Whorls four. Surface smooth or covered with very fine concentric lines. Average dimensions, hight 7 mm, width 5 mm. Distinguished from H. gaspesia

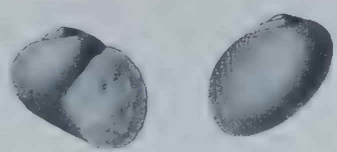
Holopea wakehami

by its rounder, more compact form, fuller whorls and more depressed spire. This species is in some of its expressions almost a miniature of the common Macrochilus hamiltoniae Hall of the Hamilton shales of New York.

Middle Devonic. Gaspé Basin, P. Q.

Holopea enjalrani nov.

Small, rotund, Diaphorostoma-shaped shells with greatly expanded body whorl and low reduced spire. Whorls two and one half to three, greatly overlapping, sutures not impressed; aper-



Holopea enjalrani

ture entire, oval; base perforate. Surface of final whorl regularly convex and covered with fine regular concentric growth lines. Hight of typical example 10 mm, hight of body whorl 8 mm, width across base 12 mm.

Lower Devonic. Dalhousie, N. B.

Holopea enjalrani var. **corrugata** nov.

A shell of the same proportions as H. enjalrani carries a series of rather strong oblique corrugations on the body whorl parallel to the growth lines and somewhat swollen at the top near

the suture. It is an expression unusual at this early age though well known in Carbonic shells of similar type and as the de-

Holopea enjalrani var. corrugata

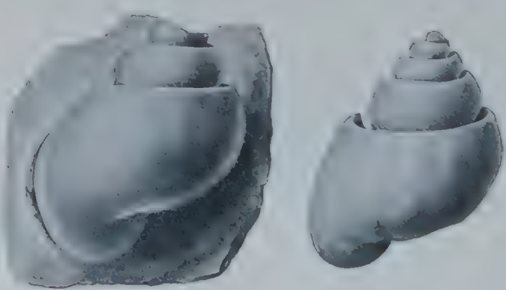
parture from H. enjalrani is alone in the clustering of the concentric growth striae into pilae, I should regard the shell a varietal expression of that species.

Lower Devonic. Dalhousie, N. B.

Holopea beushauseni nov.

Macrocheilus ? sp. Beushausen. Abhandl. z. geol. Specialk. v. Preussen etc. 1884. pl. 1, fig. 7

Shell of considerable size, stoutly subconical with sutures slightly impressed; whorls four to five, depressed convex, overlapped for one fourth to one third of their width; surface smooth or with fine concentric lines; angle of spire 40 degrees; final whorl at its commencement having a diameter equal to the hight of the spire



Holopea beushauseni

above; at the aperture much elongated, explanate or reflected in the lower part. The whorls sometimes show a slightly shouldered appearance and the final whorl may be subangular about its base. This shell occurs in great abundance in the form of distorted casts of the interior and is of the type of structure exhibited by such shells as Conchula steiningeri Koken [Neues Jahrb. für Mineral. Beilageband 6. 1889. pl. 13. fig. 2] and Bucinum arculatum (Schlotheim) MVK [Fossils Older Dep. Rhen. Prov. 1842. pl. 32. fig. 1]. With the former it may be directly

compared. Both of these shells are from the Middle Devonic. Beushausen figures as Macrocheilus ? sp. an internal cast of like aspect and proportions from the Spiriferensandstein of the Oberharz (Bocksberg), identical indeed so far as identity can be indicated by internal casts. Specially noteworthy is the agreement in relative size of the final whorl and the explanate form of the apertural margin.

Lower Devonic. Presque Isle stream. A shell of somewhat similar character but apparently stouter with more convex whorls occurs at Edmunds Hill, Chapman Plantation, Me.

Coelidium strebloceras nov.

An extremely elongate and terete shell with not less than 20 volutions at full growth. The best preserved specimen has a length of 70 mm, and a width at the base of 11 mm. The later whorls display a sharp median angulation with a moderately broad and

Coelidium strebloceras

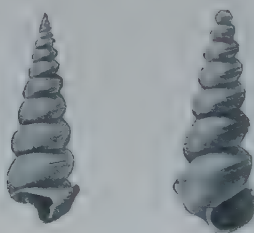
distinct slit band from which the slope to the suture is abrupt, more distinct and flattened above, more convex below.

This singularly delicate "Murchisonia" carries to an extreme the expression presented by some of the species described by Hall from the Guelph and by Lindstroem from the Gothlandian.

Lower Devonic. Dalhousie, N. B.

Coelidium tenue nov.

This is an elongate, turriculate and slender shell with sharply keeled whorls margined by a simple slit band to which the surface slopes in an almost direct plane without either convex or concave curvature, the surface of the whorls bearing reflected concentric lines. The species comes very close to Kayser's Murchisonia losseni [Fauna des Hauptquartzites, p. 15, pl. 8, fig. 9] from the Spiriferensandstein of the Hartz and the Coblentzian of the Rhine. While approaching this form most closely it is also allied to the M. angulata Phillips var. a. MVK [Fossils Older Deposits Rhenish Provinces, pl. 32, fig. 7] from the Stringocephalus



Coelidium tenue

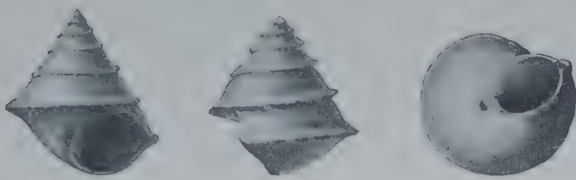
limestone of the Rhine. Attention may also be directed to the shell identified by Verneuil from the Lower Devonic of Nishnij-Tagilsk in the Urals [Geol. de la Russie, 1845, v. 2, p. 339, pl. 22, fig. 7] under the name M. cingulata Hisinger. Kayser remarks that this is not Hisinger's species, which is confined to the Swedish Upper Siluric. The forms described by Billings from the Gaspé limestone as M. hebe and M. egregia are of the same type but are stouter shells with more convex volutions. The Holopella obsoleta of Sowerby figured by Murchison among the fossils of the Tilestones may be of similar type but it is known in literature only from internal casts which serve but a faulty purpose in the determination of such shells.

Lower Devonic. Presque Isle stream, Chapman Plantation, Me. Abundant also at Dalhousie, N. B.

Eotomaria hitchcocki nov.

Shell with rather low, somewhat concave spiral of four to five whorls, the spire usually much depressed when in the shales. The surface of the whorls is regularly sloping, very slightly concave, giving an almost uninterrupted slope to the spire. Periphery

of body whorl sharply carinate or even extended into a keel or flange which seems to carry a slit band. Aperture sharply angulated exteriorly, subcircular in outline, thickened and slightly excavate on the inner lip. Base of shell broad and nearly flat for its full width. Fine concentric growth lines are the only sculpture. It is possible that this shell may be of similar character to the Trochus ? helicites Sowerby from the Tilestones of Horeb Chapel [*see Siluria*, pl. 34, fig. 12] but comparison can be



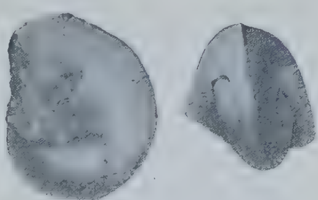
Eotomaria hitchcocki

based only on the resemblance of the internal casts of the two shells for of the exterior of the latter we have as yet no definite knowledge. It is instructive to observe that the Spiriferensandstein of the Oberharz (Bocksberg) carries an Eotomaria of similar style with extended peripheral flange [Pleurotomaria kleini Beushausen, *Beitr. zur Kenntn. d. Oberharz. Spiriferensandst.* 1884. pl. 1, fig. 10], though a shell of much larger type than that here described.

Lower Devonic. Presque Isle stream and in the burnt lands 2 miles west, Chapman Plantation, Me.

Eotomaria ? rotula nov.

Shell small, spire greatly depressed below the level of the final whorl, so that the coiling has proceeded almost in a horizontal plane.



Eotomaria ? rotula

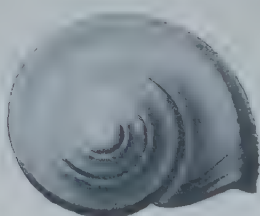
Whorls about two, gradually expanding and all in contact. Outline of body whorl bilaterally subsymmetrical, expanding on the

lower side to the stoma. It bears a peripheral elevated or convex band which is bounded above by a sulcus, though not so well defined below. The upper shoulder of the whorl is subcarinate while the lower surface is broadly rounded and bears an oblique sulcus on the final third of the volution. Aperture sinuous, projecting above and reentrant in a broad curve below the position of the peripheral band. Surface crossed by fine concentric lines which curve forward on the upper surface of the whorl and make a retral turn on the periphery whence they again curve forward in a broad sweep, on the lower surface being interrupted by the interior sulcus.

Lower Devonic. Grande Grève, P. Q.

Trochonema lescarboti nov.

Shell moderately large, trochiform. Whorls broadly sulcate above, gently convex peripherally and regularly convex below; three to four in number. Sutures impressed and bounded by an elevated ridge or carina within which the surface is depressed in a broad and shallow sulcus bounded outwardly by a sharp keel



Trochonema lescarboti

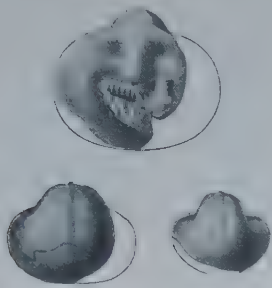
which lies at the shoulder of the whorl and from which the whorl surface is abruptly depressed. No peripheral band is known though the internal cast bears a peripheral depression. Lower surface not known except from the cast, apparently regularly convex. Surface marked by regular concentric lines without revolving striae.

Lower Devonic. Percé rock, P. Q.

Phragmostoma diopetes nov.

A small bellerophontid with well developed slit band and apparently smooth surface save for regular concentric growth lines. The shell expands rapidly to an explanate mouth which involves

the spire and forms a broad flat plate on the posterior region with the callus about the spire extending into the aperture, making a



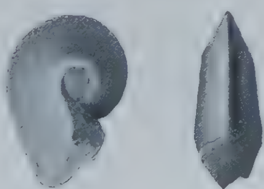
Phragmostoma diopetes

structure altogether similar to that of P. natator (Portage group), the type of the genus.

Lower Devonic. Matagamon lake, Me.

Tropidodiscus obex nov.

This is a species of unusual interest in that it represents the only member of the genus known, save the type T. curvilineatus (Conrad) from the Onondaga limestone of New York. The Maine shell is smaller than that, very sharply keeled, narrowly umbilicated,



Tropidodiscus obex

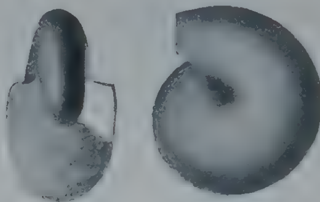
with the outward slope of the whorls direct and without evidence of revolving sulci, the inner slope being vertical. The surface is crossed by fine concentric growth lines bending sharply back to the keel.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Euphemus ? quebecensis nov.

To this well known Carbonic genus I refer with doubt flat or discoid, involute, horizontally coiled shells having a goniatitic aspect, the final whorl deeply overlapping the preceding and closing

the umbilicus. The whorls are narrow but deep, abruptly curved on the periphery; the stoma expanded but not explanate. The surface is marked by regular simple and continuous elevated revolv-



Euphemus ? quebecensis

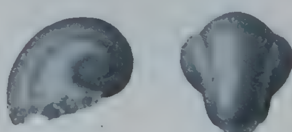
ing lines which become crowded toward the aperture. There is no evidence of a slit band. The shell has a diameter of 10 mm.

This species represents a very unusual type of structure for a Devonic bellerophontid but is provisionally placed in this association.

Middle Devonic. Gaspé Basin, Gaspé.

Bellerophon (Plectonotus?) gaspensis nov.

Shell rotuloid, rapidly expanding; expanded but not explanate at the aperture. Outer surface trilobed by two revolving lateral furrows which start early and become wider and deeper with age. These do not divide the surface equally but the lateral divisions



Bellerophon (Plectonotus) gaspensis

are considerably narrower than the median division which is broad, prominent and elevated but flattened on top and may have had a peripheral seam. The specimen measures 12 mm in diameter and has about the same apertural width.

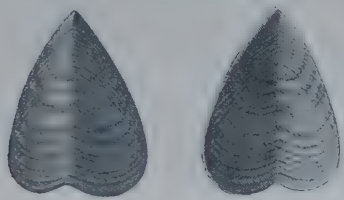
Lower Devonic. Grande Grève, P. Q.

Probolaeum ? canadense nov.

We are disposed to regard as a representative of the Polyplacophora or chitons an elongated semicone-shaped plate sinuate on its front margin, with a posterior terminal beak and broadly infolded posterior margin. The characters of this plate are shown in the

figure drawn from a sculpture cast, displaying the sharp concentric growth lines which are crowded together on the infolded part of the test. The length is 28 mm and the anterior width 19 mm.

In the Devonic of the Appalachian gulf no chitons have been



Probolaeum ? canadense

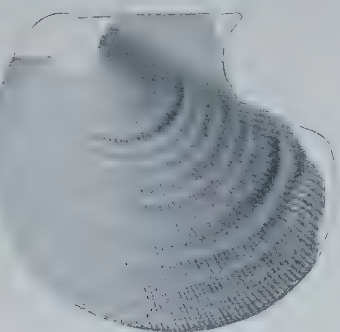
found, though these bodies are known from several horizons in the transatlantic Devonic. There is noteworthy similarity in the form and aspect of P. canadense to Chiton sagittalis Sandberger (Stringocephalus limestone).[1]

Lower Devonic. St. Alban beds, Cape Rosier Cove, P. Q.

PELECYPODS

Aviculopecten alcis nov.

Shell slightly oblique with anterior beak and short anterior wing. Hinge and posterior wing not extending as far back as the shell



Aviculopecten alcis

outline. Curvature of the margin gently convex in front and anterolaterally, narrowed and slightly produced behind. Body of the shell gently convex; length and hight equal. Surface covered by fine radial riblets of unequal size, close together, generally with some tendency to fasciculation behind, fine and fainter and closely crowded in front. These are all crossed by very fine concentric

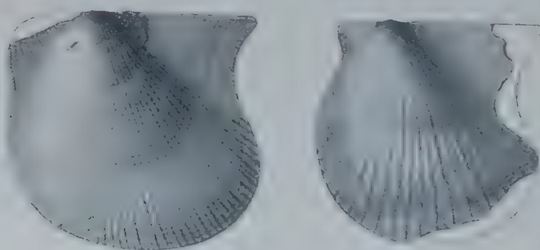
[1] Verstein. rhein. Schichtensys. p. 239, pl. 26, fig. 23.

lines and coarse concentric wrinkles which are quite irregularly spaced. This description is based wholly on a left valve to which it has seemed unsafe to refer any associated right valves. Though there are ribbed Aviculopectens in all the formations here brought under consideration I know none which agrees with or approaches this.

Lower Devonic. Moosehead lake, 7 miles north of Kineo, Me.

Aviculopecten flammiger nov.

This is a shell of somewhat variable exterior which approaches in outline the Pterinopecten proteus Clarke of the Becraft Mountain Oriskany [*see* N. Y. State Mus. Mem. 3, p. 32, pl. 4, fig. 7], but it is unlike that in exterior. The round subcircular shell is strongly radiated, the primary radii being sometimes coarse with broad fascicles of intermediate striae, sometimes



Aviculopecten flammiger

finer and less distinctly fasciculate. In the number of these primary ribs there is the greatest variation. All are crossed by sharply elevated concentric striae. The anterior wing is deeply sulcate and sinuous, the posterior relatively large and with concentric striae only. Only left valves of this species have been observed and they are readily recognized in spite of their variable ornament.

Lower Devonic. Askwith siding, Misery stream and Moose river, Me.

Aviculopecten jumeaui nov.

Shell of considerable size, suberect, explanate below, with suborbicular outline tending to obliquity posteriorly. Beak anterior, anterior wing short, posterior broad flat or subconcave, the point not extending beyond the posterior curve of the shell; sharply incurved on the lateral margin. Surface with fasciculate bands somewhat after the type of ornament in Actinopteria textilis; coarse distant ribs with intermediate smooth spaces divided

by a simple low rib, these interspaces being subdivided near the margin. Concentric sublamellose lines at distant intervals. On

Aviculopecten jumeaui

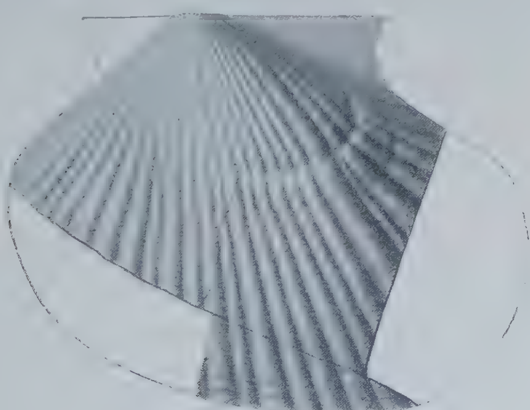
the wing radial lines are obscure but concentric lines sharp and crowded.

Dimensions. The typical specimen has a length of 47 mm; hight of 42 mm.

Lower Devonic. Percé rock, P. Q.

Aviculopecten ? incrassatus nov.

Shell large, outline obliquely subelliptical. Posterior wing short. Surface with coarse and heavy radial ribs of unequal size separ-



Aviculopecten ? incrassatus

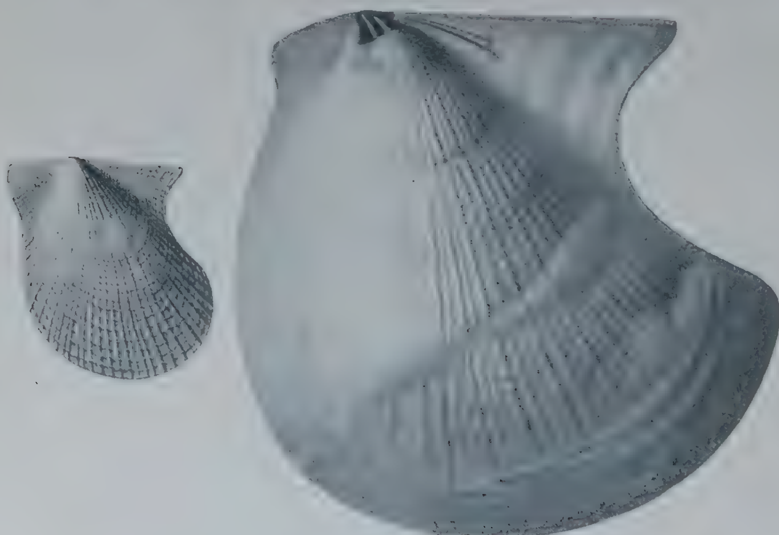
ated by relatively narrow rounded grooves. Inequality in the size of the ribs is noticeable in the umbonal region and new ribs are

added by division of the large ones. All are crossed by a concentric ornament of fine compressed lines with occasional deep concentric growth furrows. This type of ornamentation is an extreme condition of that sometimes expressed by Pterinopecten proteus. The original specimen has a hight of 50 mm and a probable length of 70 mm.

Lower Devonic. Grande Grève, P. Q.

Actinopteria (Pterinea) fronsacia nov.

This is a species having somewhat the aspect of the common and well known A. boydi of the Hamilton fauna of New York, but more erect and with a larger auricle. Its surface is marked by quite regularly alternating radii and these are crossed by imbricating concentric lines which are closely crowded together



Actinopteria (Pterinea) fronsacia

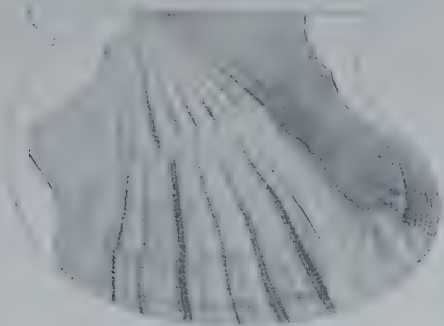
and crenulated fore and aft. In A. boydi the radial riblets are of more uniform size and as usually preserved in the shales show only inconspicuous evidence of the lamellose concentric lines here present. More closely allied in ornament and in form is the A. eschwegii Clarke[1], from the Lower Devonic Maecurú sandstone of the Amazonas.

Middle Devonic. Gaspé Basin, P. Q.

[1] Archivos do Mus. Nac. Rio de Janeiro. 1899. 10:45, pl. 5, fig. 9.

Pterinopecten denysi nov.

Shell moderately large, subcircular, known only from its left valve which in the single specimen before us is somewhat incomplete about the hinge but has a very characteristic sculpture. This consists primarily of a few strong radial ribs of unequal size, which rapidly spread apart leaving broad interspaces which do not, in any noticeable degree on the body of the shell, become occupied by other ribs, except small and simple ones of a secondary series.



Pterinopecten denysi

The primary ribs themselves widen, become broad and flat and split up into lesser ones, though all derived from the division of any rib may remain together in a fascicle. On the anterior part of the shell the diffusion of the riblets is less defined and regular. All these are crossed by very fine reticulating concentric striae. This is a style of irregular sculpture which with more specimens would probably prove to be quite inconstant and is in a measure reproduced in the very variable species from the Oriskany of New York, which we have designated as P. proteus. A similar aspect is presented by the P. wulfi Frech from the lower Coblentzian of the Eifel.[1]

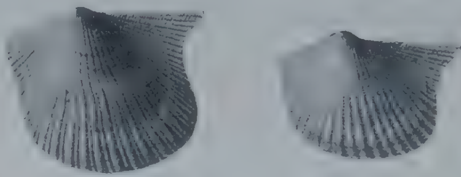
Lower Devonic. Dalhousie, N. B.

Pterinopecten aroostooki nov.

Shells subcircular or somewhat transverse with outline slightly extended posteriorly; beak at the anterior third of the hinge, posterior hinge straight, reaching to the extreme limit of the outline, posterior wing very slightly extended; anterior hinge straight, anterior wing moderately large but undulated, an oblique ridge traversing it from the beak just beneath the hinge leaving the portion behind it depressed and flat. Below this ridge the ear is de-

[1] Devon. Aviculiden Deutschlands, p. 25, pl. 2, fig. 7.

pressed or broadly sulcate. Umbo convex, narrow; pallial region sloping evenly downward and depressed. The surface sculpture consists of well defined ribs, which are broad and sparse over the median region where they usually carry one very small rib between each two of the large ones. On the anterior slope and wing these



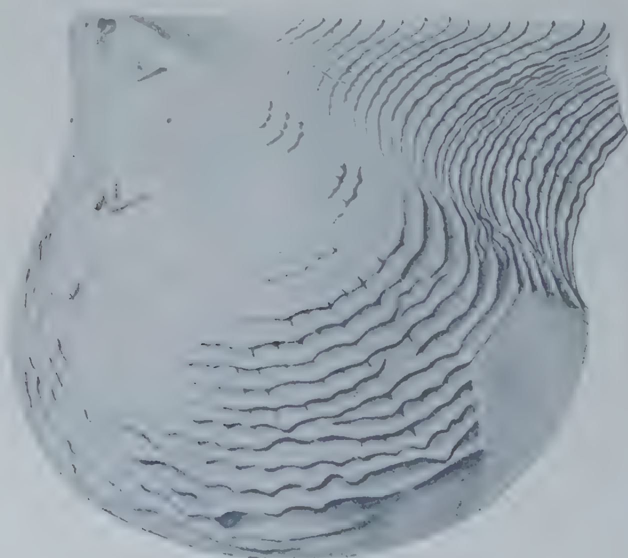
Pterinopecten aroostooki

ribs are smaller and also on the posterior slope and wing. Cancellating lamellae cross the posterior wing and are visible in the sulci of all the posterior surface of the valve. The left valves only are known.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Limoptera rosieri nov.

This large and rather fine species has a flabellate outline with umbones almost at the anterior end of the hinge. The hinge line



Limoptera rosieri

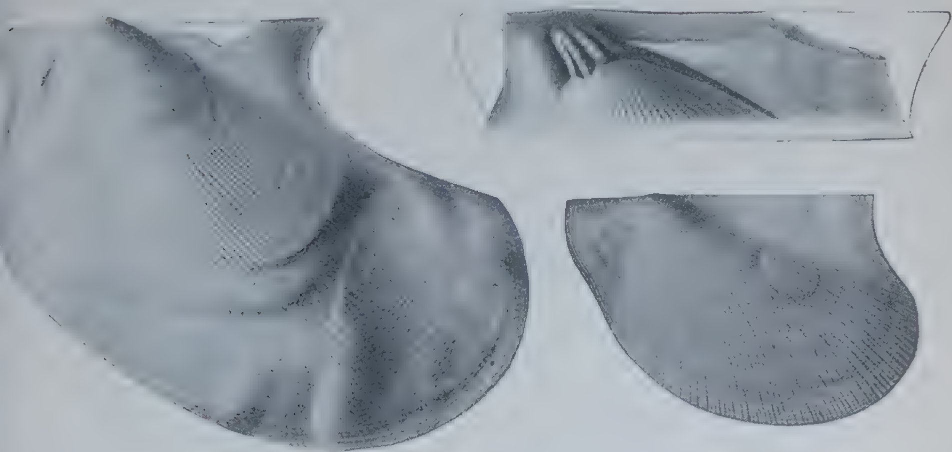
is very long and straight terminating posteriorly on the extreme point of a very broad wing. The incurvature from this wing

toward the body of the shell is but slight, but the area is set off by a low, broad depression on the surface and a distinct change of curvature in the surface lines. The body of this shell is broad and transverse, the curvature being regularly suboval, while the anterior course of the margin is much more direct, curving outwardly below and slightly incurved above. The anterior wing is very small, separated from the umbones by a deep sulcus. The ligament area is very broad and is longitudinally lined. The ornament lines of the surface consist of distinct concentric lamellae, becoming more closely arranged near the margins. Their interspaces are crossed and the lamellae themselves notched or crenulated by subequally distant elevated radial lines. The reticulated and fimbriated effect is specially shown on the posterior wing. Our specimens show the following dimensions: Length on hinge, 100 mm, hight and length of body, 90 mm.

Lower Devonic. St. Alban beds, Cape Rosier Cove, P. Q.

Pterinea mainensis nov.

Shell often of large size, oblique, hinge considerably shorter than the full length of the valve. Anterior wing well developed, but slightly sloping at the hinge and set off from the shell body



Pterinea mainensis

by a low broad sulcus. Posterior wing relatively short not reaching the posterolateral limit of the valve and sometimes not more than one half or two thirds this distance. Body of the valves depressed not sharply set off from the wings; anterior outline at first direct, then inclining more or less rapidly backward and often

extended at the posterolateral margin from which the retreat toward the posterior wing is abruptly oblique. The surface of the left valve is covered by fine radii, equal on the anterior slope but unequal on the posterior and showing a tendency to fasciculation. These are minutely cancellated by concentric lines which on the anterior slope and wing and on the posterior slope become prominent to the exclusion of the radii. The right valve is shallow, evenly depressed, with the radii along the crescence line stronger and more distant and the cancellating lines subdued.

The hinge is distinctly pterineoid, showing a doubly divided umbonal tooth, strong oblique posterior ridge and broad, striated ligament surface.

This shell, extraordinarily abundant at some localities, is readily recognized by its extremely fine radial surface markings accompanying unusual size.

Lower Devonic. Telos lake dam and Moosehead lake, 7 miles north of Kineo, Me.

Pterinea moneris nov.

Somewhat oblique valves with hinge line less than the greatest length, anterior beaks, and moderately developed posterior wing.

Pterinea moneris

The surface is depressed and entirely devoid of radial markings on either body or wing, thus only concentric lines or rough wrinkles are present.

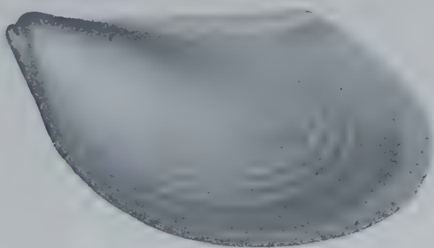
The umbonal teeth are strongly developed in the left valve as a set of three oblique ridges, behind them being a strong oblique ridge. What may prove to be the right valve of the species has a more convex surface, strong anterior muscle scar and teeth to correspond with the sockets of the other valve.

This species is like but much more oblique than the P. follmanni Frech and P. laevis Goldfuss of the Coblentzian.

Lower Devonic. Webster lake, north side, ¼ mile east of Telos canal and Matagamon lake, on east side 1 mile above dam, Me.

Pterinea chapmani nov.

A large left valve has the beak almost terminal, a long straight hinge, lateral teeth not visible but umbonal teeth sharply defined; posterior wing narrow and not extended, anterior wing very small; anterior slope abrupt, almost vertical; umbo narrow elevated, the



Pterinea chapmani

general surface of the valve broadly convex; outline oblique. The surface carries faint radial riblets, which are obsolete on the anterior slope.

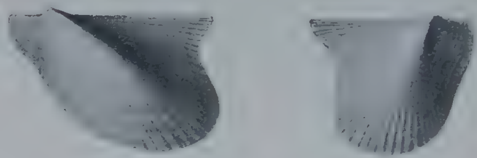
The species differs from any of its associates in its obliquity, abrupt anterior slope, abbreviated anterior wing and short posterior extension.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Pterinea edmundi nov.

The distinguishing marks of this species are found in its ornament and variable outline. In aspect it approaches very closely the P. radialis from Presque Isle stream but its left valve is sometimes more oblique, sometimes more erect, its umbonal convexity less marked. Its sculpture consists of coarse flattened ribs which are more or less irregularly interspersed with ribs of smaller size; on the anterior slope these gradually disappear leaving the

anterior ear smooth, but on the posterior slope they are continued to the hinge. The posterior wing is cancellated and the cardinal line more strongly striate. The left valve which is less convex than the other has the radial riblets developed only on the median area, both anterior and posterior wings being smooth save on the



Pterinea edmundi

posterior hinge where is a cancellated group of three or four strong radii. The variations in the outline of this species reach an extreme in the variety subrecta, which retains the same style of ornament as the foregoing and relative proportions and development of the parts, but is quite erect. This appears to be a persistent feature which we find exemplified in several examples.

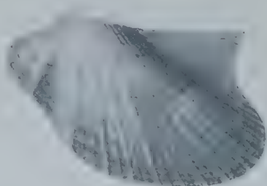
Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

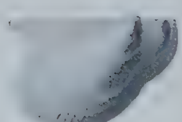
Pterinea cf. fasciculata Goldfuss

Pterinea fasciculata Goldfuss. Petrefacta Germaniae, 2:137, pl. 129, fig. 5

Pterinea fasciculata Frech. Devon. Aviculiden Deutschlands 1891. p. 84, pl. 8, fig. 1; pl. 9, fig. 1–3

This species is radially and coarsely ribbed, quite convex and oblique along the crescence line, the anterior wing strongly





Pterinea cf. fasciculata Goldfuss

developed on the abrupt anterior slope and the hinge teeth both beneath the beak and behind it very pronounced. It is very

like the species cited in all respects so far as the former is known. It is, however, possible that some of the coarsely ribbed internal casts may belong to the more finely marked form to which we refer in the following.

Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

Pterinea fasciculata Goldfuss var. **occidentalis** nov.

See Pterinea fasciculata Goldfuss. Petrefacta Germaniae, 2: 137, pl. 129, fig. 5, and Frech. Devon. Aviculiden Deutschlands. 1891. p. 84, pl. 8, fig. 1; pl. 9, fig. 1–3.

This extremely common shell is essentially a miniature of P. fasciculata Goldfuss. Though reduced in all its proportions and in the strength of its ornament yet it expresses excellently the characters of the German species. The valves are both convex, the left notably and the right but slightly. The left valve has the body well elevated above the posterior wing. This wing is sometimes more incurved at the margin and more extended at the point than in the figured German specimens but these features are variable in the Dalhousie shells. The body of the shell or direction of the crescence line is commonly more oblique than in European specimens but this is an expression due in some measure to mode of preservation, for examples occur here quite as erect as those referred to. The breadth of the byssal groove and emargination on the valve are also notable; together with the relative development of the anterior ear they are in full agreement with P. fasciculata. The surface of this valve is marked by coarsely fasciculated radial striae. The major ribs do not exceed five or six but these are widely separated on the body of the shell, the interspaces occupied by radii of lower order.

On the posterior slope the striae are of uniform size and are visible on the wing. On the anterior wing there are two or three coarse riblets but the byssal sinus is deep and without radii. Crossing these elevated radial lines are fine crowded and elevated concentric lines giving all the surface except the byssal sinus a reticulate ornament.

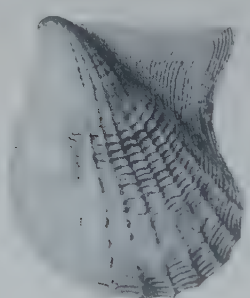
The right valve is much less convex than the left, the anterior wing relatively large, the byssal sinus deep, the body of the shell

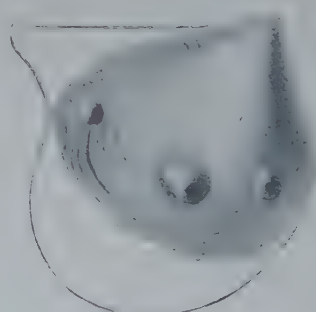
depressed. The surface bears a few simple filiform radial lines along the body of the shell and others are visible on the posterior wing at the hinge. No concentric lines are evident.

Lower Devonic. Dalhousie, N. B.

Pterinea intercostata nov.

Shell suberect or oblique with small auricle and well defined, broad but not extended posterior ear. Hinge straight, about two thirds the greatest diameter of the shell. Beaks anterior, subterminal. Left valve with coarse and strong radial ribs separated by broad flat interspaces. Of these one can count about 12 on the body of the shell. The primary interspaces are usually divided by a much finer median riblet but further subdivision is very unusual. On the broad posterior wing radial ribs are sparse and indistinct though usually traces of them may be seen. Here the fine concen-





Pterinea intercostata

tric lines predominate, giving the surface a smoothness in contrast to the rest of the valve. The concentric lines are also visible on the rest of the surface. As usually preserved they make faint interruptions of the radial ribs but when normal are lamellose and strongly defined. The right valve is practically devoid of radial sculpture, the surface being crossed by sharply defined concentric lines, only the posterior wing showing a few riblets on the cast. The contrast in the markings of the two valves is extreme but is conclusively demonstrated by several specimens with both valves retained.

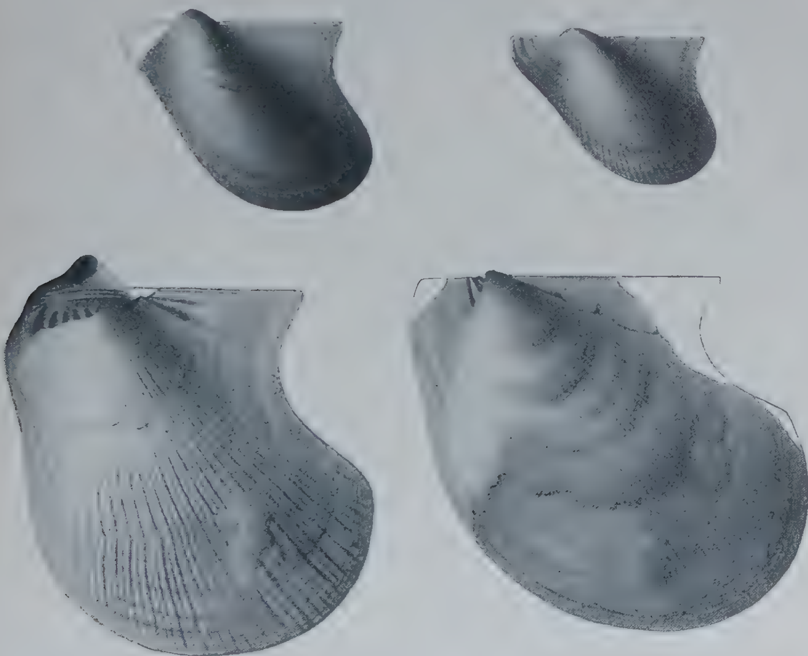
This species may be compared in respect to ornament with several coarsely ribbed shells, e.g. P. costata Goldfs., Avicula

r i g o m a g e n s i s Frech, from the Coblentzian, A. r e t i c u l a t a Sowerby, from the Aymestry limestone, but such comparisons are resemblances only in one or another feature. No closely allied form is now recognized.

Lower Devonic. Dalhousie, N. B.

Pterinea radialis nov.

This is one of a group with an Actinopterialike exterior, but it has the highly developed anterior muscle scar, the umbonal and the lateral teeth of Pterinea. No attempts therefore at correlation with species which have been determined as Actinopteria and Avicula are here called for. The shells have the size and propor-



P t e r i n e a r a d i a l i s

Upper figures the usual form at Chapman Plantation; lower figures exemplify the larger size attained at Matagamon lake.

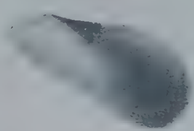
tions of the foregoing (P. cf. f a s c i c u l a t a) and the following species. The hinge line is but slightly extended posteriorly, the anterior wing well marked, convex and sulcated; the crescence line oblique and the valve highly convex in the umbonal region, with abrupt anterior and more gradual posterior slope. The sur-

face sculpture consists of closely crowded subequal rounded riblets, alternation of size being noticeable near the margins.

Lower Devonic. Presque Isle stream, Chapman Plantation, Matagamon lake and elsewhere, Me.

Pterinea ? mytiloides nov.

A Leptodesmalike shell, extremely oblique and elongate with a subacute anterior extremity, anterior beak, short hinge, oblique broadly rounded umbonal ridge terminating in a broad blunt posterior extremity. The lower margin of the valve makes at the



Pterinea ? mytiloides

anterior extremity an angle of about 40 degrees with the hinge, is slightly incurved by the broad and obscure cincture in front of the umbonal ridge.

Dimensions. The best preserved example has a length from anterior end to postlateral curve of 25 mm; hight from the beak 7 mm; greatest hight 12 mm.

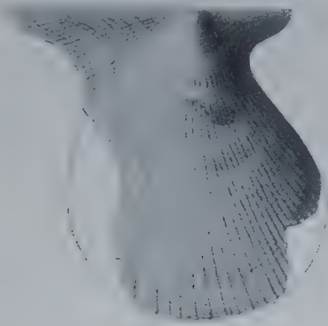
This species is provisionally referred to Pterinea and it is more than doubtful if it has any immediate relations with Leptodesma Hall in the sense in which that name was employed by its author. Its age and surroundings indicate that it has direct pterineoid affinities. The shell is rare but its form leads to its ready recognition.

Lower Devonic. Dalhousie, N. B.

Pterinea brisa nov.

An elongate shell, quite erect, the axis of growth being essentially at right angles to the hinge. The body is produced and moderately expanded; the wings distinctly developed but not large, the posterior being narrow, the anterior short and the byssal sinus well defined. The length of the hinge in the specimen before us is 32 mm, the vertical hight 40 mm. The beak is at the anterior third of the hinge. The surface is marked by radial elevated lines with broad, flat interspaces, broken by intercalated lines of minor series. In the

umbonal region the lines are close together but they spread outward and the primary interspaces become broad. The body of the



Pterinea brisa

valve shows few concentric lines but these are strong on the wings and those on the posterior wing are cancellated by the radii near the hinge.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Pterinea brisa var. vexillum nov.

A right valve is suberect with a semicircular lower margin, deep byssal sinus, short but well defined anterior wing and broad posterior wing extended to an acute posterior angle. Its surface is flat or slightly concave in the pallial region. The sculpture con-

Pterinea brisa var. vexillum

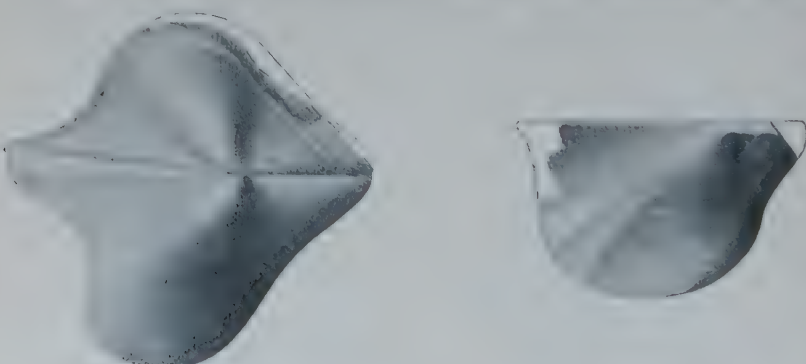
sists of fine radial riblets of subequal size moderately distant and numerous over the body of the valve, very obscure on the posterior wing, which is entirely covered by concentric crowded lamellose lines; the latter are extremely faint over the rest of the shell. A less complete specimen in which the left valve is impressed upon the right shows that the surface of the latter was crossed by very strong radial and very distant ribs, the broad flat interspaces some-

times carrying intercalating ribs of lower order. These were crossed by concentric lines, presumably lamellae. The aspect of the surface is thus not unlike that of P. intercostata but the outline is very different and the right valve is distinctly ribbed. The species P. brisa from Chapman Plantation, the description of which is based on a right valve, is a very close approach to this in respect to outline and surface characters, though a more elongate, erect shell. To express this intimate relation the present form is regarded as a variety of the latter.

Lower Devonic. Dalhousie, N. B.

Pterinea (Pteronitella?) incurvata nov.

Valves elongate on the hinge, the greatest length of the hinge being almost twice the hight of the shell. Anterior wing well defined on both valves, byssal sinus not deep but broad and not marked by a notch on the right valve. Beaks one third the length of the hinge from the anterior extremity. General outline very oblique. Left valve highly convex and incurved over the body, sloping abruptly to the posterior wing, more gradually to the



Pterinea (Pteronitella?) incurvata

broad byssal sinus in front. From the prominent umbo the crescence line swings in a curve backward and forms a strong projection on the lower margin. The posterior wing is extended well beyond the posterior margin of the body and bounded by a concave curve which terminates in an acute point. Its surface is depressed in a direction conforming with the curve of the body. The surface of this valve is covered with regular concentric growth lines which are essentially unmodified on the anterior and posterior wings but the body of the valve bears radial striae which have

somewhat the aspect of unequal and flat riblets produced by series of incised lines. These multiply and broaden unequally presenting much the same aspect as those in P. edmundi of the Chapman Plantation.

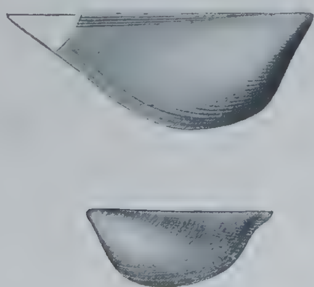
The right valve is depressed; on the posterior wing deeply concave, convex but not elevated along the crescence line, thence sloping to the lower margin with an incurved surface, the postlateral edge of the valve being upturned. The byssal notch and sinus are indicated by a marginal incurvature and depression. One specimen shows the striated ligament area, a small anterior adductor and slender anterior tooth. Surface of this valve entirely smooth or with concentric lines only.

This shell is characterized by its extreme convexity and incurvature.

Lower Devonic. Dalhousie, N. B.

Pteronitella hirundo nov.

Shell much elongate on the hinge, terminating posteriorly in a slender, acute point, anteriorly blunt, the auricle atrophied and the anterior slope of the valves abrupt. Beak subterminal, elevated, umbonal ridge subparallel with the anterior margin. From this ridge the surface of the left valve slopes very gradually



Pteronitella hirundo

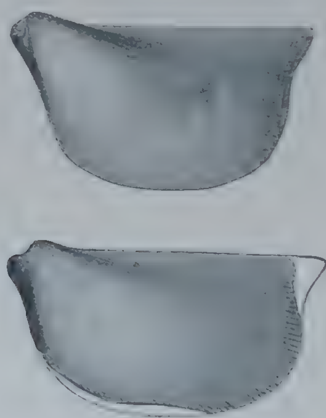
downward and back; right valve flat except at the beak. Surface of left valve bearing sharp and numerous radial lines, crowded and with a tendency to fasciculation over the anterior and lower parts but equidistant posteriorly. The hinge and ligament areas are bounded and crossed by a few very strong striae, the cardinal edge of the valve being thickened. All these lines are crossed by concentric striae, short and elevated everywhere except on the posterior cardinal surface. On the right valve the radial lines are obsolete

except on the posterior wing near the hinge, only the concentric lines standing out sharply and equidistant. The inner surface of both valves is quite smooth. This is a striking species well defined by its outline and surface characters. Its thin shell has left insufficient evidence of its dentition but I have referred it to Pteronitella largely because of its general aspect.

Lower Devonic. Dalhousie, N. B.

Pteronitella passer nov.

This differs from the preceding in presenting a less extended and rather blunt posterior extremity, a more conspicuous anterior ear and a relatively greater breadth. The outline is still elongate with a gentle surface slope on all sides except the front where it



Pteronitella passer

is quite abrupt. The surface is fully reticulated by radial and concentric lines, the former being as before stronger along the posterior wing.

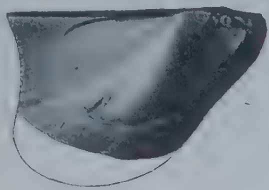
In my judgment this will be readily distinguished by its outline as exhibited in two left valves here figured, though it is undeniably similar to P. hirundo in many of its characters.

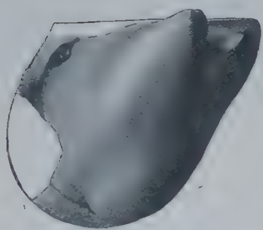
Lower Devonic. Dalhousie, N. B.

Pteronitella peninsulae nov.

Very sharp internal casts of right valves show the characteristic structure of this genus as defined by Billings, clearly demonstrating the departure from the type of Pteronites in the presence of a series of Cyrtodontalike teeth beneath the beak together with the

long posterior ridgelike tooth. These valves are very oblique, the straight hinge making the greatest diameter of the shell; the anterior wing is insignificant and the posterior not extended. From





Pteronitella peninsulae

anterior and posterior cardinal angles the lateral margins depart at almost 90 degrees. The beak is very near the anterior extremity and the shell is quite convex along the oblique and somewhat curved crescence line, from which the anterior slope is abrupt and the posterior abrupt and slightly concave at first becoming flat at the hinge. The anterior scar is small and deep, the posterior large and faint. Beneath the beak are three or four teeth diverging from the edge of the ligament area.

Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

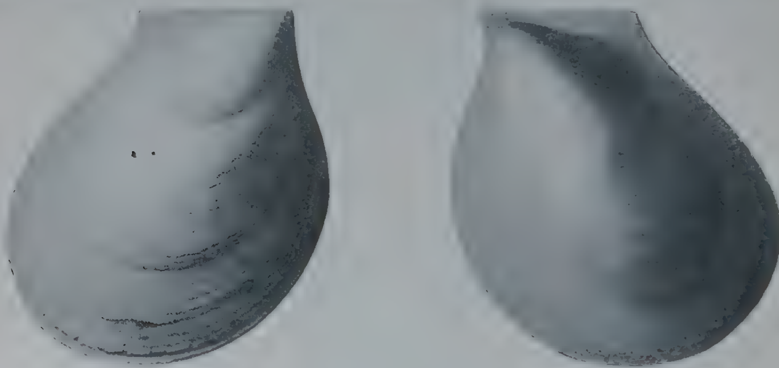
Myalina pterinaeoides nov.

One of the commoner species at Presque Isle stream is a Myalina with a striking resemblance throughout, save in the character of the hinge, to certain Pterineas with curtailed posterior wing, and specially similar to Pt. follmanni Frech.[1]

The frequent internal casts show the species to be devoid of the hinge teeth of Pterinea and present only the moderately broad ligamental striations of Myalina and the abbreviated earless and abrupt front margin. This latter feature is rather feebly developed but when the shell is retained the anterior incurvature

[1]Frech. *op. cit.* pl. 10, fig. 5: Drevermann. Fauna d. Untercoblenzsch, p. 82, pl. 10, fig. 1, 2.

with margins truncated and meeting at right angles is evident. In other respects we may note the following characters: The shell is relatively suberect without posterior hinge, obliquely elongate, suboval with greatest width across the pallial region, the hinge line being short, not more than one half as long as the length



Myalina pterinaeoides

of the shell. The valves are shallow and thick; posterior muscle scar well defined, situated at one half the length of the shell; pallial line short, barely reaching beyond the middle; anterior scar absent.

The surface of the shell is coarsely rugose in concentric growth lines and is without other ornament. Of such a species as this we know nothing among the faunas of the Appalachian early Devonic.

Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

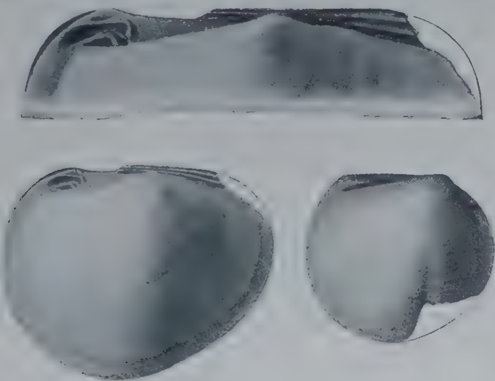
Cyrtodonta beyrichi Beushausen

Cyrtodonta beyrichi Beushausen. Beitr. zur. Kenntn. d. Oberharzen Spiriferensandsteins. 1884. p. 67, pl. 3, fig. 2, 3.

I am disposed to refer to this species without much reservation certain subcircular shells of Paracyclaslike outline with quite convex surface, slightly depressed behind and faintly sinuous in front. In these the hinge has the structure of Cyrtodonta strongly developed—the curved double anterior teeth and the long lateral or posterior grooves and ridges. Beushausen's figures were made from internal casts but they display the general outline and size of those before us.

The genus Cyrtodonta has not been observed in the Devonic rocks of the Appalachian province and its occurrence in the eastern

region is of decided interest. While these Devonic species seem to agree in hinge structure with those which have been referred to the genus from the Lower Siluric yet it is possible that differences may be found and Beushausen's recognition of the



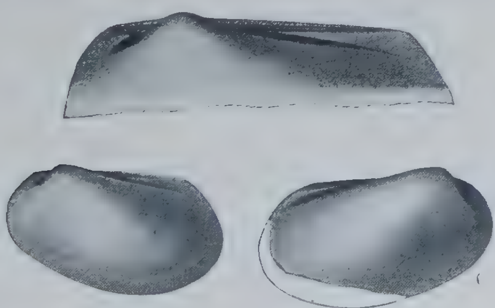
Cyrtodonta beyrichi

validity of Cyrtodonta which has commonly been regarded a synonym of Conrad's term Cypricardites, has been indorsed by Ulrich [Paleontology of Minnesota, 1897. v. 3, p. 534] who has elaborately illustrated the Siluric species. Cyrtodonta beyrichi in Germany occurs in the Spiriferensandstein of the Hartz mountains at the Kahleberg.

Lower Devonic. Moosehead lake, 7 miles north of Kineo, Me.

Cyrtodonta muscula nov.

Much more elongate than the preceding, retaining the pterineoid



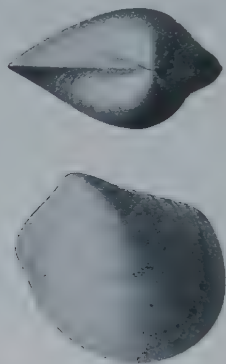
Cyrtodonta muscula

form, narrow in front, widening backward and with a broad anterior sinus. Hinge as in the other species.

Lower Devonic. Moosehead lake, 7 miles north of Kineo, Me.

Megambonia denysia nov.

Shell very small, suborbicular in outline and rotund in contour. Auricle not prominent, byssal groove broad shallow and indistinct, but visible nearly to the beak. Surface very finely radiate on the body of the shell but with fewer radii on the auricle. The



Megambonia denysia

orbicular outline, regular convexity and feeble byssal groove seem to indicate this as distinct from M. crenistriata Clarke, though not varying materially in surface characters. Further knowledge of the shell may determine a closer relationship in the two.

Lower Devonic. Percé rock, P. Q.

Mytilarca dalhousie nov.

Cf. M. ovata Hall. Palaeontology of New York, 3: 279, pl. 50, fig. 7.
M. solida Maurer. Fauna d. rechtsrhein. Unterdevon. 1886. p. 13; Frech. Devon. Aviculiden Deutschlands, p. 143, fig. 15.

Mytilarca is not common in early Devonic faunas. The specimens of the genus from the Dalhousie fauna are well developed in respect to generic characters and of moderately large size approaching in dimensions the Helderbergian species Megambonia ovata Hall which has never been well described or figured though its relation to Mytilarca has long been recognized[1]; and in outline and contour Myalina solida Maurer of the Lower Coblentzian where such species are rare. Mytilarca dalhousie is elongate subovate in outline, with short straight posterior hinge and long abruptly deflected anterior margin extending to the basal curvature of the valves with a slightly sinuous curve. The surface is regularly but slightly convex with the

[1] N. Y. State Mus. Mem. 3, p. 89

greatest elevation along the anterior crescence line and the slope thence gradual in all directions except anteriorly, where it is curved down and inward. The general expression of the shell will be better appreciated from the figures than by description. There are large and small shells present with these characters all representing the same specific form.

The hinge characters are excellently shown in one specimen of the left valve. The beak is terminal; beneath it is the apex of the broad ligament area which is strongly striated transversely.

Mytilarca dalhousie

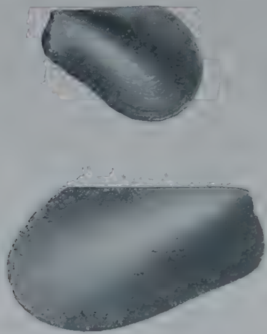
The anterior edge of this area slopes obliquely back to the inner apex of the valve and at this point is a single oblique elongated tooth, doubly crenulated on the crest leaving between it and the edge of the ligament area a pit or socket for the reception of the tooth of the other valve. This socket is bounded below by a continuation of the tooth. Toward the posterior end of the hinge is an oblique but obscure ridge below the ligament area. This hinge structure is in agreement with Hall's delineation of it for the genus Mytilarca. The umbonal region of the shell is thick and the posterior margin shows successive thickened layers of shell growth.

Lower Devonic. Dalhousie, N. B.

Modiomorpha impar nov.

Shell of small or medium size with straight hinge line not extending for the full length of the valves. Beaks anterior but not terminal, depressed, the umbonal region rising gradually and soon broadening out over the low posterior slope. In front of this ridge

the surface is gently depressed making a distinct sinus in the lower margins specially on the left valve. Anterior margins



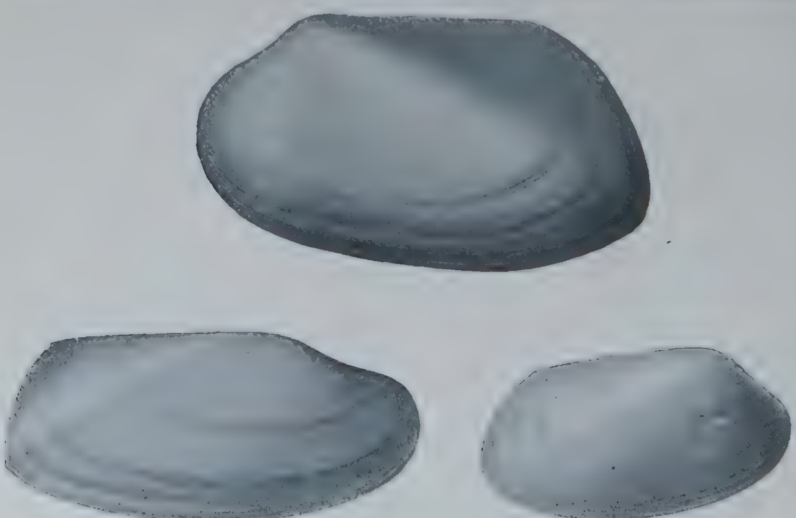
Modiomorpha impar

relatively narrow and blunt, posterior extremity broadly rounded. Postumbonal slope gently concave. Surface covered with regular concentric lines.

Lower Devonic. Dalhousie, N. B.

Modiomorpha odiata nov.

Shells elongate, depressed convex and of considerable size; beak at the anterior third, hinge short, anterior curvature relatively nar-



Modiomorpha odiata

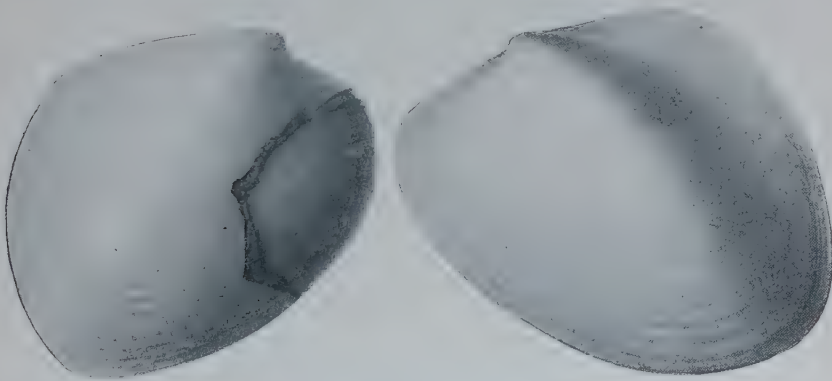
row, the valves widening backward in a low very broad curve, umbonal ridge low but clearly defined making a flat or depressed

posterior slope and rather straight posterior margin. Length about twice the hight; actual length of a full sized example 60 mm, hight 35 mm. Surface with concentric lines only.

Lower Devonic. Moosehead lake, Baker Brook point and Matagamon lake, Me.

Modimorpha vulcanalis nov.

Shell robust, with very thick valves; outline short, obliquely cordate, hinge line oblique, beak in front of the middle, not elevated; umbonal ridge low but distinct from which the slope anteriorly is broad and very gently convex while posteriorly it is at first gently concave, then depressed and almost flat near the hinge line. The marginal outline is narrow in front at the ex-



Modiomorpha vulcanalis

tremity of the oblique hinge, widens in a low curve backward, turns almost at right angles at the end of the crescence line, curving thence broadly upward and forward, joining the obliquely elevated hinge in a broad curve. The length and width of the shell are nearly the same.

The resemblance of this species to Drevermann's Goniophora cognata[1] is very close in all visible features save that the crescence ridge in the latter is somewhat sharper. It may also be compared to M. elevata Krantz of the lower Coblentzian.[2] Professor Kayser suggests a similarity with M. siegenensis

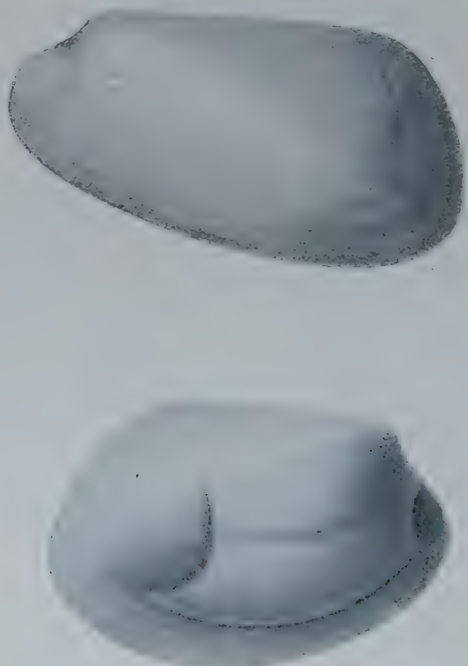
[1]Fauna d. Untercoblentzsch. 1902. p. 88, pl. 10, fig. 15, 16.
[2]Beushausen. Lamell. d. rhein. Devons, p. 23, pl. 2, fig. 9–11.

Beushausen.[1] At all events the short obliquely cordate shell is not familiar in Appalachian fauna of this age.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Modiomorpha protea nov.

Shell elongate, subrhomboidal, beaks anterior, posterior hinge not elevated, crescence line high, relatively approximate to hinge. Length and hight as four to three. Anterior margin broadly rounded, not narrow, basal margin sloping gently downward to near the umbonal ridge, thence bending up and back in a broad



Modiomorpha protea

angle; posterior hinge angle rounded. Umbonal ridge subangular, sharply defined by the rapid slope of the surface toward the hinge, but not elevated above the general convexity of the sides of the valves.

Anterior adductor scar with the little foot muscle scar well defined.

This species is somewhat variable in outline, some of the specimens assigned thereto being considerably larger than others. This

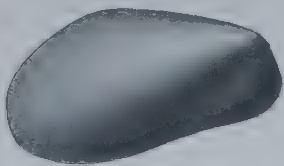
[1] *op. cit.* p. 24, pl. 2, fig. 8.

variation, however, is not expressed in the typical specimens at Edmunds Hill as well as in the examples referred to the same species occurring at Presque Isle stream.

Lower Devonic. Edmunds Hill and Presque Isle stream, Chapman Plantation, Me.

Modiella modiola nov.

This is a more elongate, more slender and generally larger shell than M. pygmaea Hall, the posteriorly expanded and convex body of the shell being narrower, the byssal sulcus less deep and



Modiella modiola

the anterior fold very much reduced in diameter. The shells are thus subacuminate or modioloid and very obliquely arcuate. Average examples have a length of 18 to 24 mm.

Middle Devonic. Gaspé Basin, Gaspé.

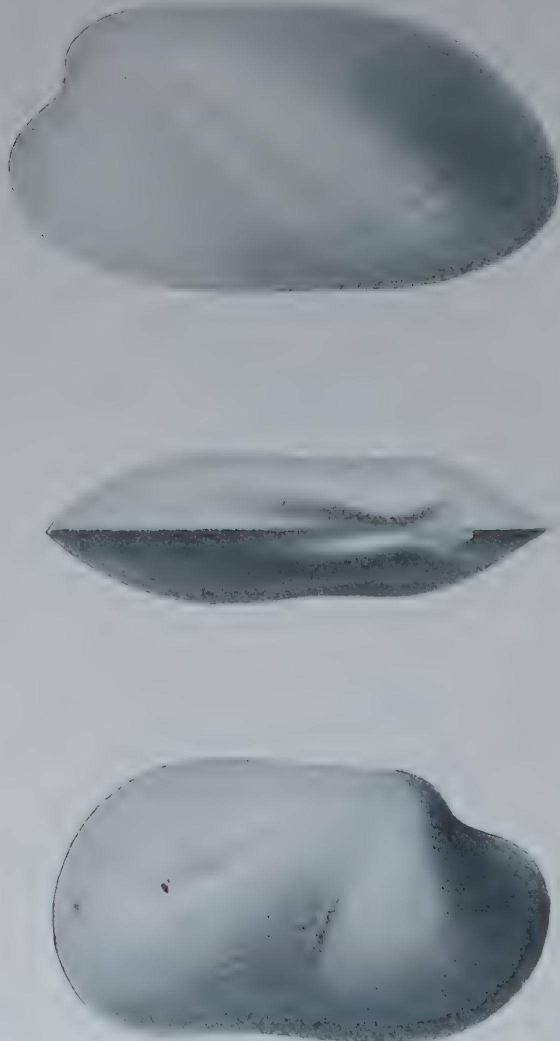
Grammysia modiomorphae nov.

Shell large, elongate, generally with strong oblique medial depression dividing the valves into two lobes, sometimes a low ridge lying in the bottom of this depression; beaks at the anterior one third of the hinge, slightly elevated, appressed and incurved; hinge line direct, not elevated; marginal outline incurved in front of the beaks, rather narrow at the anterior extremity, broadly incurving on the basal margin at the median sulcus, recurving in a broad angle at the postlateral extremity. The median sulcus varies in width and strength in different examples, at times being highly and somewhat unequally developed on both valves, rather more on the right and again being only a low, broad depression.

Muscle scars obscure, only the anterior adductor being occasionally shown on our specimens. Surface markings concentric striae strongly marked at the anterior margin.

The elongate form of this shell and its subequal extremities give it the appearance of a Modiomorpha. The evidence seems to indicate however that it is a Grammysia of unusual expression,

with which it is not easy to find comparison among other shells. Drs Kayser and Drevermann who have kindly examined specimens



Grammysia modiomorphae

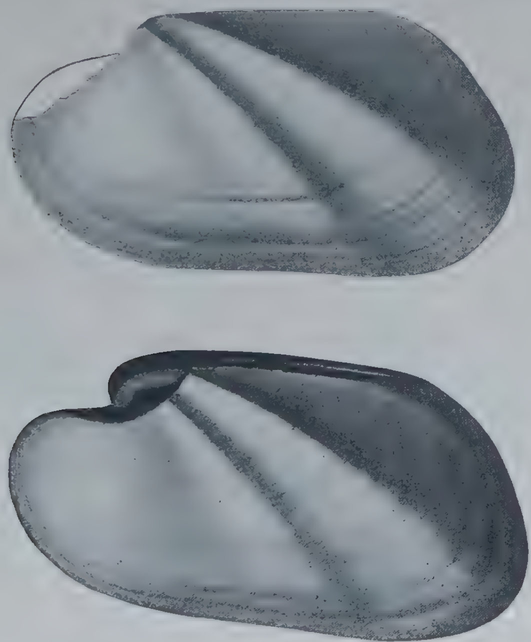
of the shell agree that it is very similar to Beushausen's G. prümiensis[1] from the upper Coblentzian of the Eifel.

Lower Devonic. This species is the most abundant of the lamellibranchs at Edmunds Hill, Chapman Plantation, Me.

[1] *op. cit.* p. 243, pl. 24, fig. 2-4

Prosocoelus pes-anseris Zeiler & Wirtgen var. **occidentalis** nov.

The genus Prosocoelus was established by Keferstein in 1857 and was first applied to the species Grammysia pes-anseris Zeiler & Wirtgen[1] by Beushausen[2] and the latter author subsequently described several species from Coblentzian horizons. The hinge in the genus is characterized by its strong and large, curved umbonal teeth, two in number, with the uppermost the larger, and in the left valve a small triangular anterior tooth; a



Prosocoelus pes-anseris var. occidentalis

broad ligament area with longitudinal groove. The exterior bears two or three strong divergent ridges. In P. pes-anseris these surface ridges have an extreme of development.

It is of extraordinary interest to find this genus, not before known outside the typical regions of the Coblentzian, present in the fauna of central Maine and by a species which bears so strong a resemblance to P. pes-anseris as to make comparison therewith more reasonable than with any other of the known forms.

The shells from this fauna are usually elongate, broader behind than in front, nearly twice as long as high, with two strongly

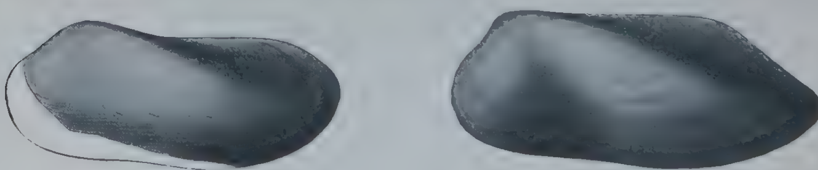
[1]Singhofen. Jahrb. des Vereins für Naturkunde im Herzogthum Nassau. 1851. p. 290.
[2]Beitr. zur. Kenntn. d. Oberharzer Spiriferensandsteins. 1884. p. 109.

defined radial ridges; the umbonal ridge, separated from the median ridge by a moderately deep broadening groove and in front of this a depression bounded by a still lower sometimes quite vague elevation. Some of Beushausen's species of Prosocoelus, especially P. ellipticus (Schalke, Hartz) have much the outline and expression of this shell. There are specimens in our collections that indicate a more orbicular outline quite similar to that of P. orbicularis Beushausen.[1] I am not altogether certain whether these represent the latter species or may be compressed specimens of the former. The evidence seems to favor the former view.

Lower Devonic. Tomhegan point, Moosehead lake, Me.

Leptodomus communis nov.

Shell elongate with a Cimitarialike curve to the hinge, beak anterior, hinge not equaling the length of the shell; lower margin sinuate, curving upward posteriorly to a narrowed, subacute extremity whence the posterior edge retreats to the hinge. Surface deeply sulcate from umbo to basal margin. Umbonal ridge conspicuous, blunt and broadly curved, exterior with low irregular concentric folds.



Leptodomus communis

Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

Leptodomus corrugatus nov.

Shell small, beak at the anterior third of the hinge, outline subelliptical, posterior slope gently sulcate, smooth, anterior surface coarsely corrugated and over the median area these anterior ridges duplicate, there being on the whole on the lateral slope two

Leptodomus corrugatus

[1] *ibid.* p. 110, pl. 5, fig. 8.

ridges for every one on the anterior surface. Median surface slightly depressed.

Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

Leptodomus prunus nov.

Elongate shells with anterior umbones and low cincture most distinct at the beaks. Surface quite evenly convex though the beaks are depressed. Umbonal ridge broad and ill defined. Ornament consisting of concentric ridges, sharp in the umbonal region

Leptodomus prunus

and with closely crowded concentric lines between all, becoming obscure toward the margins. Length of each valve about twice the hight.

This species is distinguished from L. canadensis Billings of the Grande Grève limestone by its shallower cincture but further knowledge of the species may show its very close relationship to L. striatulus F. Roemer of the upper Coblentzian. [For figures of the latter *see* Beushausen. *op. cit.* p. 265, pl. 24, fig. 12-14]

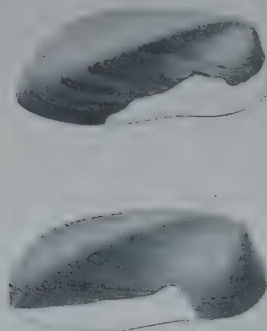
Lower Devonic. Telos lake, Blind Cove Point, Me.

Goniophora curvata nov,

Shell of medium size, elongate, hinge line usually concealed, but apparently short, not extending posteriorly to within one third of the shell's length of the end. Beaks anterior, subterminal, valve slightly excavated in front beneath them, making the anterior extremity relatively narrow. The umbonal ridge is obliquely curved and lies high on the valves making the postumbonal slope narrow.

The specimens of this shell are not common and it would seem the width of the postumbonal slope and the position of the ridge

are subject to variation by compression. In forms where this post-umbonal slope is broader the shell approaches the Orthonota solenoides Sow.,[1] of which specimens are before us from the



Goniophora curvata

Upper Ludlow of Bradnor lane, Kingston. The latter shell, however, is broader and more produced behind and has a shorter and more oblique hinge line.

Lower Devonic. Dalhousie, N. B.

Sphenotus ellsi nov.

Shell elongate, subrectangular, hinge line and lower margin parallel. Beak at the anterior fourth of the hinge, anterior slope

Sphenotus ellsi

uncurved, anterior margin broadly rounded. Umbones not elevated, flattened and divided by a sinus or cincture which traverses

[1]Murchison. Siluria. Ed. 3. pl. 23, fig. 9.

the valves obliquely backward though without greatly affecting the regularity of the basal margin. Umbonal ridge sharply developed, not crested; extending to the postlateral angle. Postumbonal slope broad and concave, its outer edge constituting the entire posterior margin of the valve which slopes forward to the hinge. This concave area is traversed by an obscure radial ridge. Surface of the valves covered with fine concentric striae in low and irregular undulations over the shell body; these however are absent on the posterior slopes where sharp concentric lines alone are visible. Length about one third the hight.

Lower Devonic. Dalhousie, N. B.

Carydium elongatum nov.

This is distinguished from its associate C. gregarium Beushausen by its longer and narrow valves which are quite regularly convex from a transverse median line, the surface sloping thence uniformly above and below, leaving the umbones depressed. The

Carydium elongatum

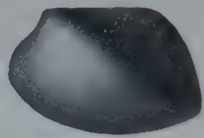
anterior end is visibly narrower than the posterior though the latter is not greatly expanded. The beaks are situated about one third the hinge length from the anterior end and the region in front of the beaks is somewhat excavated. The hight of the shell is about one third of the length. The surface is covered by concentric lines only.

Lower Devonic. Dalhousie, N. B.

Cypricardella norumbegae nov.

Shell short, subrectangular, broader behind than in front, beaks well forward, umbones prominent, umbonal ridge well developed and dividing the valves so as to leave a broad postumbonal slope which is slightly depressed or concave. Hinge line short, not extended in front. Shell margin curving from a broad anterior extremity with an outward bend into the basal margin which becomes direct near the umbonal ridge where it turns sharply

almost at right angles, curving outward, upward and forward and joining the hinge in an obtuse angle. Hinge with the characteristic



Cypricardella norumbegae

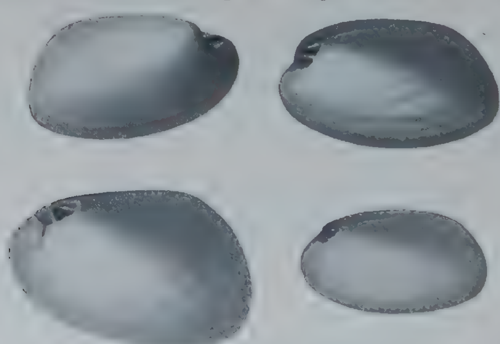
median tooth just beneath and in front of the beak on the left valve.

Shell substance thick, surface with regular concentric growth lines and sometimes a vague radial fold in the postumbonal slope.

Lower Devonic. Dalhousie, N. B.

Cypricardella parmula nov.

These are small shells of oval outline with an almost uniform convexity, beaks well toward the front and very low umbonal ridge. They are about one third longer than high and are especially noteworthy for the strong development of the umbonal teeth,



Cypricardella parmula

which are slightly curved ridges, the median one much the strongest, bounded by deep sockets and a more subdued tooth above and below.

There are no Cypricardellas of this type in the New York faunas where they are chiefly characterized by sharp concentric lines and strong umbonal ridge. Such shells as these are however very closely similar to C. bicostata Krantz and C. elongata Beushausen,[1] especially to the former.

Lower Devonic. Moosehead lake, a little north of Soccatean point, Me.

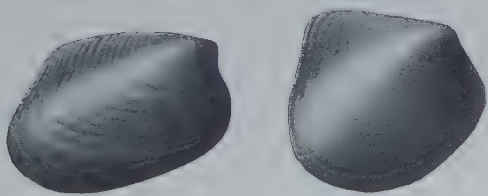
[1] *See* Beushausen's figures, *op. cit.* pl. 11, fig. 5-14.

Cypricardinia magna nov. or cf. **crenistriata** Sandberger

See Sandberger. Verstein. d. rhein. Schichtensystems. 1850-56. p. 263, pl. 28, fig. 5

Beushausen. Lamellibr. d. rhein. Devon. 1895. p. 178, pl. 16, fig. 9-13

Shell large for this genus, somewhat variable in outline but usually obliquely rhomboidal with very strong umbonal ridge, anterior beaks, very decided postumbonal slope which is deeply incurved, narrow anterior extremity widening backward. Hinge somewhat curved, shell extended behind, lower margin slightly incurved and sinuate. Length and greatest hight as six to five, actual length 30 mm, high 25 mm. Some specimens are quite



Cypricardinia magna or cf. crenistriata

erect with the hight and length equal. Surface bearing strong concentric lamellose and quite regular sculpture, on which the finer ornamental lines occurring in many other species have not been retained.

This shell in its size and proportions is very closely like C. crenistriata as figured by Beushausen from the lower and upper Coblentzian of the Rhine. Species in the Grande Grève limestone (C. distincta Billings) attain its size and C. planulata Hall (Schoharie grit) has a similar contour but no other form than that above cited is known to us which approaches it both in size and contour.

Lower Devonic. Moosehead lake, Baker Brook point, Me.

Cardiomorpha (Goniophora ?) simplex nov.

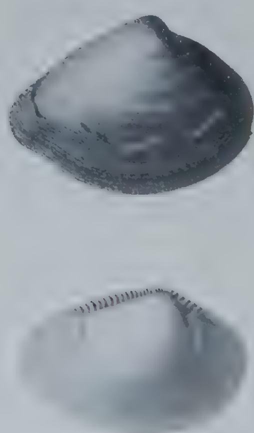
Shells elongate with anterior beaks; narrow in front, widening behind and with a very high and bluntly angular umbonal ridge behind which is an abrupt posterior slope and in front a well marked sinuosity or radial depression. The posterior extremity of the shell is quite narrow and subacute.

The hinge is well displayed in some specimens and is peculiar for its simplicity; there is a moderately broad striated ligament area which widens slightly beneath the beaks but there is, under the most favorable preservation, no evidence whatever of the umbonal teeth which exist in the typical forms of Goniophora. Therefore the suggestion of relationship to that genus is wholly based on the general aspect of the exterior. The shell is generally about twice as long as high and many attain a length of 50 mm. Surface sculpture simple concentric lines. Beushausen referred to Cardiomorpha such toothless shells, including within his diagnosis a large variety of external expressions, among others forms having this Goniophoralike exterior [*see* especially C. alata Sandb. in *op. cit.* p. 223, pl. 25, fig. 15-17].

Lower Devonic. Moosehead lake, north of Soccatean point, Me.

Palaeoneilo mainensis nov.

Shell attaining large dimensions for a species of the genus, subtrihedral, depressed convex, with beak but little in front of middle of the hinge. Hight three fifths of the length. Posterior surface gently sinuate and the postlateral shell margins corres-



Palaeoneilo mainensis

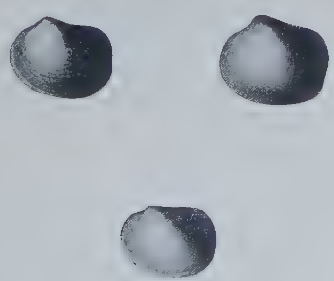
pondingly emarginate, extremities narrow. Surface covered with fine concentric growth lines. On the interior the muscle scars are deeply inpressed, there being on the umbonal side of each a ridge but both anterior scar and ridge are very much the more strongly marked and almost attain the strength of the ridge in Nuculites.

The hinge has the following structure: The posterior arm carries a row of 16-18 ligament pits ending at the anterior edge of the posterior adductor. Those directly under the beak are very slender and transverse, outward they become stronger and more and more chevron-shaped; the anterior arm is not separated by an oblique line from the posterior and carries seven or eight pits, increasing outward rapidly in size and becoming strong and oblique at the terminus near the inner edge of the adductor. In respect to hinge structure, the species is readily distinguishable from P. orbignyi, which it sometimes resembles in form. It is not easy to find European or Mississippian species which this shell resembles in form and hinge structure. Comparisons of similarity are readily made with species of the Devonic on both sides of the Atlantic but these are not helpful in the absence of agreement in critical details. We may however observe that the shell occasionally puts on a concentrically wrinkled surface which we find together with agreements in outline, convexity and, so far as can be ascertained, in hinge structure, expressed in P. maureri Beushausen and some of its variants in the Coblentzian fauna. [Beush. *op. cit.* p. 85, pl. 7, fig. 11-28]

Lower Devonic. Abundant at Presque Isle stream and 2 miles westward in the burnt district, Chapman Plantation, Me.

Palaeoneilo circulus nov.

Shell small, almost circular in outline, slightly oblique, depressed and evenly convex, with beak somewhat anterior, surface marked



Palaeoneilo circulus

by the fine elevated concentric lines characterizing so many species of this genus and with a very low posterior sulcus. Muscle scars slightly buttressed by shelly ridges.

Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

Nucula cf. krachtae A. Roemer

Nucula krachtae A. Roemer. Verstein. des Harzgebirges, 1843. p. 23, pl. 6, fig. 10

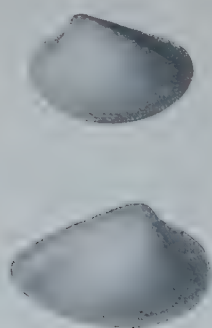
Nucula krachtae Beushausen. Lamell. des rhein. Devon. 1895. p. 47, pl. 4, fig. 20

I am disposed to identify with this well known Coblentzian species a small trihedral Nucula of great obliquity and prominent overarching beaks.

Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

Palaeoneilo (Nuculites) folles nov.

This is a species of the type of Nuculites branneri Clarke from the Maecurú river[1] and Cucullella ovata Sow. from the Tilestones of Horeb Chapel[2] but while it approaches both of these very closely there is only the barest indication in the specimens before us of the anterior clavicle shown by a slender depression in the sculpture casts while the other characters of the



Palaeoneilo (Nuculites) folles

shell are those of Palaeoneilo, even to the presence of a slight posterior sinuosity or oblique depression which brings it into comparison with P. orbignyi Clarke from Maecurú[3] in which the surface is covered with very fine concentric lines, and with a number of more coarsely marked sinuous species from the Coblentzian.

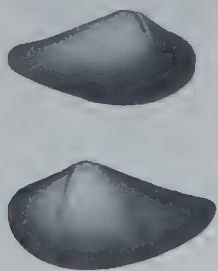
Lower Devonic. Dalhousie, N. B.

[1] Archivos do Mus. Nacional Rio de Janeiro. 10: 73, pl. 8, fig. 6-8.
[2] Murchison. Siluria. Ed. 3. pl. 34, fig. 17.
[3] *op. cit.* p. 74, pl. 8, fig. 14-17.

Nuculana (Ditichia) securis nov.

Cf. Nuculana securiformis Goldfuss (sp.) Petrefacta Germaniae. 2: 151, pl. 124, fig. 8 and Beushausen, Devon. Aviculiden Deutschlands, p. 59, pl. 4, fig. 26-28

Shell small, transversely elongated and snouted, beak approximately median, hinge line sloping slightly in front, deeply incurved behind. Posterior extensions narrow, curved gently upward at the extremity, anterior extremity broad and blunt; umbones not prominent, umbonal ridge obscure; greatest convexity of the valve anterior near the hinge; surface generally convex over the body of the shell, depressed toward the posterior extremity; hinge toothed almost to the extremity of the posterior extension, while the marginal surface along the extension is excavated and slightly ridged. Just within the position of the muscle scars which are usually faint are two faint shell ridges or clavicles preserved as grooves on the sculpture



Nuculana (Ditichia) securis

casts. Of these the anterior is the larger, both are broad and low, but the structure is altogether unusual though not unexpected in this genus. This structure is expressed in Nuculites by the strong development of an anterior ridge and in such forms occasionally the two ridges appear as in the species N. (Cucullella) elliptica Maurer of the Coblentzian for which Sandberger proposed the generic term Ditichia because of this structure. Beushausen however considers this development of a second ridge of only specific value and embraces such species within Cucullella. For the same reason we may hold the present species within the genus Nuculana though shells of this lediform type have not before shown such structures. The presence of these muscular clavicles is the only apparent difference between this shell and the Nuculana securiformis Goldfuss of the Coblentzian.

The surface of the valves is covered with very fine concentric striae.

Lower Devonic. Dalhousie, N. B.

Macrodus matthewi nov.

Shell quite small, obliquely ovate, much broader behind with obliquely curving lower margin and broadly rounded posterior extremity. The hinge is not long and slopes at its posterior end to the posterior curve. The beak is well forward, nearly terminal,

Macrodus matthewi

umbones prominent, umbonal ridge arched, oblique, high, fading out posteriorly. A broad sinus lies medially in front of the umbonal ridge and produces an inward curve on the lower shell margin. Length and posterior hight of the shell nearly the same.

Lower Devonic. Dalhousie, N. B.

Macrodus ? baileyi nov.

Shell small, elongate, gradually expanding backward. Beaks at about one third the length of the hinge from the anterior extremity. Hinge line rounding broadly backward. Umbonal ridge or crescence line high, posterior, well defined in early growth

Macrodus ? baileyi

but becoming obscure in later stages. Anterior extremity well rounded, the lower margin of the valves incurving medially and rounding again to the broader and rather blunt posterior extremity. The surface of the valves is rendered concave medially by a broad not sharply defined sinus passing from the umbones to the lower margins. Contour quite regularly convex on each side of the sinus.

The length of the shell is somewhat less than thrice the hight. Surface smooth. The hinge structure of this shell has not been definitely determined but the species is provisionally referred to Macrodus.

Lower Devonic. Dalhousie, N. B.

Palaeosolen simplex Maurer

Solen simplex Maurer. Fauna d. rechtsrhein. Unterdevon. 1886. p. 18

Palaeosolen simplex Beushausen. Lamellibr. d. rhein. Devon. 1895. p. 224, pl. 18, fig. 9, 10

The specimens before us though not abundant in our collections seem to present no distinction from the lower Coblentzian shell

Palaeosolen simplex

referred to, and we are disposed to assign them to that species without further question.

Lower Devonic. Moosehead lake, a little north of Soccatean point; also on Presque Isle stream, Chapman Plantation, Me.

Conocardium incarceratum nov.

This species will be found a close ally of C. inceptum Hall, whose form and surface characters as occurring in the Oriskany of Becraft mountain I have already delineated in New York State Museum Memoir 3. The shell sometimes attains a larger size than the New York species; its form is the same but its exterior differs in the following particulars. The ornament is not so fine, the radial lines less numerous and the deep concentric lamellae can be traced continuously across the shell while in C. inceptum they are so interrupted by the radial ribs on the body of

the shell as to form radial rows of deep meshes which often alternate in their position in adjoining rows. The meshes in C. incarceratum are much the larger transversely. The anterior ridge is sharply elevated and crested, the anterior slope very abrupt, excavated and striated by the elevated concentric lamellae which here take on a radial attitude. The posterior termination is extended and acute and the valves gape at this end. These specimens show very clearly the structure of the sculpture or prismatic layer of the shell in these species, which is rendered distinctly

Conocardium incarceratum x3

cavernous by the projection of the concentric growth in the form of pronounced lamellae rising from the deep intervals between the ribs and dividing these areas into series of elongate pit-shaped meshes.

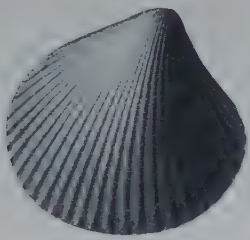
I have been disposed to regard these shells identical with C. rhenanum as described and figured by Beushausen [*op. cit.* p. 402, pl. 30, fig. 5–8]. There is agreement between the two in respect to size, form and radial markings but the lamellar surface structure is not defined in sufficient detail to determine whether it corresponds to that of the Dalhousie shell or that of C. inceptum Hall. As there is a palpable difference herein we have preferred to give these shells a distinctive designation. Conocardium rhenanum is from the Coblentz quartzite and the Upper Coblentzian of the Rhine.

Lower Devonic. Dalhousie, N. B.

Lunulicardium ? convexum nov.

Cardiform, beak anterior, outline obliquely orbicular. Surface convex, elevated about the umbo, which is full and overarched, abruptly deflected on the anterior slope. Anterior marginal curve at first concave, thence rounding rather abruptly at the extremity, posterior curve much broader and postlateral surface somewhat

expanded. Surface bearing round, threadlike and simple radii separated by very narrow sulci. On the single right valve observed



Lunulicardium ? convexum

there are 26–28 of these radii which extend over the entire surface.

Length and hight equal.

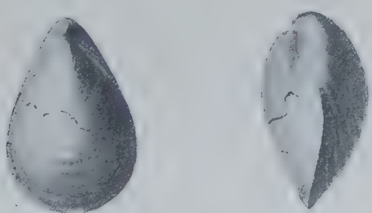
This is a small shell which, with the general aspect of a Lunulicardium, fails to reveal the critical structural features of that genus.

Middle Devonic. Gaspé Basin, P. Q.

BRACHIOPODS

Cryptonella ? ellsi nov.

Shell elongate with relatively slender and projecting umbones and sloping cardinal margins. The beak of the ventral valve is arched but not incurved, the lateral slopes broad and excavated,



Cryptonella ? ellsi

bounded without by long cardinal ridges extending one half the length of the shell. The valves are subequally convex but the ventral valve is flattened toward the anterior margin. Width of valves to length as two to three.

Lower Devonic. Grande Grève, P. Q.

Rensselaeria ovoides Eaton (sp.) var. gaspensis nov.

Analyzed as to exterior characters this shell is a miniature of the great R. ovoides of the New York Oriskany, varying in proportion, dimensions, outline and convexity, much as that shell does, that is, frequently high-shouldered and broad across the umbones, rarely broadest in the pallial region, often with lateral margins vertical or slightly introverted specially about the umbones, but as often without this character, usually with the ventral valve medially elevated, and finally with a diversity in the character of

Rensselaeria ovoides var. gaspensis
Left hand figure, Gaspé sandstone; central, Grande Grève; right hand, Percé

surface striation which is due to the fact that the fine striae of early age maintain their simplicity but increase in width without additions, to that in old shells or progressed stages of relatively young shells where the surface may seem to be coarsely marked. On the other hand the shells are characterized by a prevailing narrow elongate-linguate outline with parallel lateral margins for a great part of their length. On the interior there are few notable and perhaps no constant differences, whether in respect to structure of musculature or cardinal plate. It is, however, here important to bring forward the fact which the writer has already expressed with some emphasis, that as between the genera Rensselaeria (as based on the type species R. ovoides) and its chronologic successor Amphigenia, there is a distinction solely in one structural

point. In form and nearly every detail of outline, surface and contour, in musculature, cardinal arrangement, brachial structure so far as known and in intimate shell structure they are homogenic. In Amphigenia however the converging dental plates do not reach the bottom of the valve but first unite and the resultant spondylium is supported on a short median vertical septum. In Rensselaeria the plates converging, fail to unite but meet the inner wall of the shell leaving between them a narrow surface, which is in effect the base of the spondylium. In this special feature which can hardly be accredited with high value as an anatomical differential, there is a definite indication of progress. The Gaspé shells show how frail is this conventional distinction. The convergence of the dental plates leaves only a very narrow space between and quite frequently they come together at the very surface of the shell wall. Even a single vertical septum may develop in the later forms of the Gaspé sandstone. It is natural to compare the small elongate shells from Gaspé with Hall's R. marylandica from the Cumberland Oriskany. They are shells of the same proportions but in respect to development of the dental lamellae the latter is rather less progressed than R. ovoides.

In view of the evidence presented by these Gaspé shells it seems to us very desirable to regard Amphigenia essentially synonymous with Rensselaeria and indicating as we have said a progressed condition of one feature only. Rensselaeria has many specific expressions and among the forms now referred to it are several more significant departures than that presented by A. elongata.

Lower Devonic. Grande Grève and Percé.

Middle Devonic. Gaspé Basin, P. Q.

Rensselaeria stewarti nov.

Shell naviculate, the unequal convexity of the valves being very marked. The ventral valve is highly convex and arched, the line of greatest curvature being median from which the slope is somewhat abrupt to the sides giving the valve a subcarinate exterior. The umbo of this valve is high and overarched, projecting far beyond the hinge line, the apex being incurved and truncate. The cardinal area is represented by a flattened triangular area free of striae and rather definitely delimited. The dorsal valve is gently and evenly convex with low and inconspicuous umbo and beak. The surface of both valves is covered by abundant subequal radial riblets all of which are simple and continuous from beak to margin

except in rare instances where additions are introduced. There is considerable difference in the coarseness of the radial marking in mature shells, the number being as low as 40 and as high as 80 to 90 on each valve.

The radial lines are crossed by exceedingly fine concentric striae. On the interior the ventral valve shows a deep muscle scar and strong dental plates, the former not being striated by the plications

Rensselaeria stewarti
The four upper figures somewhat enlarged

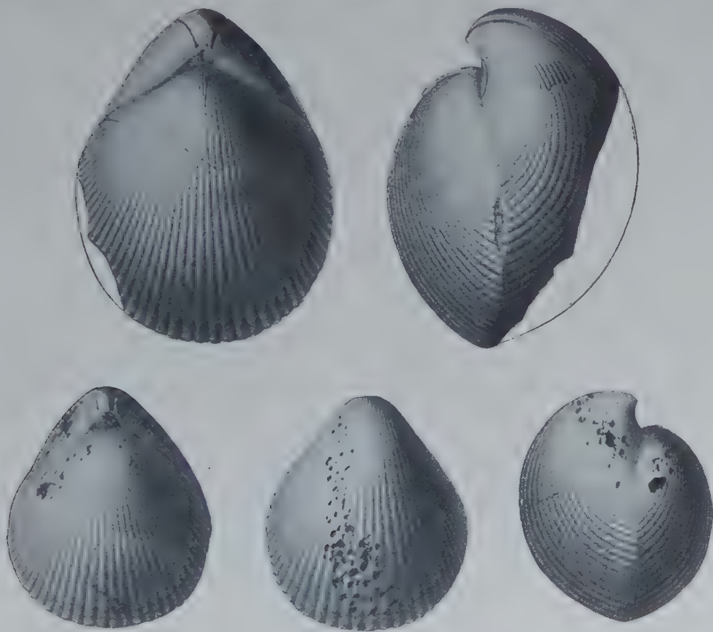
of the shell. On the dorsal valve is a defined cardinal area, perforated hinge plate and narrow elongate muscle area divided by a faint median septum.

We have spoken elsewhere of the relations of this and similar shells to Trigeria and of the presence of such forms both in the Oriskany and Helderberg faunas. We have identified in the Cumberland Oriskany, Trigeria gaudryi Oehlert [*see* Paleontology of New York, v. 8, pt 2, pl. 76, fig. 6, 7] and T. portlandica Billings from Square Lake, Me. is a somewhat similar shell. Both however lack the specific characters of the shell before us.

Lower Devonic. Dalhousie, N. B.

Rensselaeria callida nov.

On other pages we have entered into some discussion of the species of Rensselaeria of Trigerialike form occurring in Aroostook county and at Dalhousie and have indicated their affinities with the Coblentzian species R. strigiceps and R. crassicosta. We have before us now extensive representations of two additional species occurring in association which while presenting some aspects of similarity to the species referred to (R. atlantica and



Rensselaeria callida

R. stewarti) are not in full agreement with them. One of these here designated as R. callida occurs in various stages of growth but the adult form is of considerable size, attaining a length of 50 mm and upward. Its valves are full, convex with a tendency to gibbosity, the ventral valve being broadly and faintly keeled and the dorsal valve slightly flattened medially, the ventral umbo elevated and arching but not incurving over the other. The outline is quite regularly oval. Beneath the beak the incurvature shows no evidence of flattening into a cardinal area as in the species cited nor is there evidence of such area on the dorsal valve. There are a well defined foraminal opening and tube and the dental plates are considerably developed extending from one fourth to one

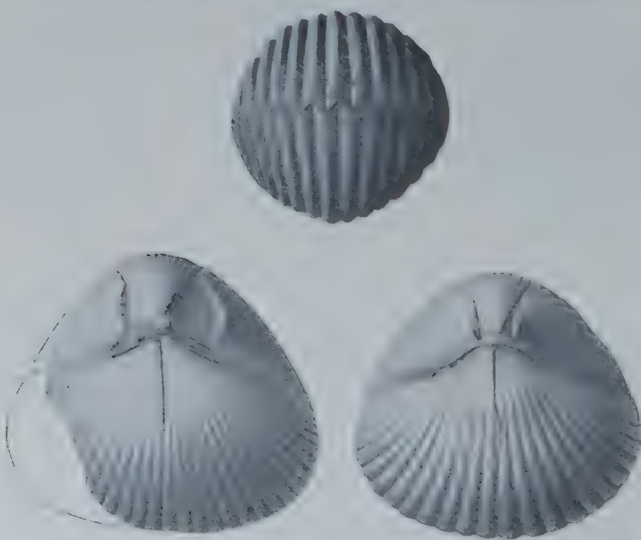
fifth the length of the valve though without thickening. There is no impressed muscular scar and no thickening of the shells in the umbonal region. In the dorsal valve, though there is a median septum extending about one third the length of the shell, there is no thickening at the beak and the hinge plate is so slender that we have been unable to make it out. All these details are in notable contrast to R. atlantica, R. stewarti and the Coblentzian species referred to.

They are in closer correspondence to the Helderberg species R. aequiradiata Hall and indicate, irrespective of their considerable size, an entirely primitive condition of development. The markings of the surface consist of simple rounded or slightly flattened plications seldom with concentric growth lines or other interruptions. There are about 50 of these simple plications on each valve, the number varying very little with size and age.

Lower Devonic. Misery stream, first dam in town of Sandwich; Brassua lake, opposite Moose river, Me.

Rensselaeria diania nov.

This species retains the contour and simple structure of R. callida but differs wholly in its exterior which carries 20 to 30



Rensselaeria diania

very coarse and broad, sometimes quite sharply keeled plications which meet in sharp interlocking angles at the edge. Its similarity

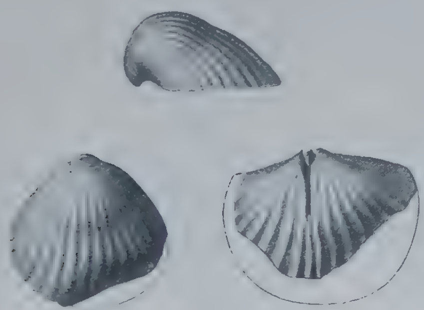
to R. crassicosta Koch of the Siegen greywacke is undeniable.

Lower Devonic. Misery stream, first dam in town of Sandwich, Me.

Rensselaeria cf. **crassicosta** Koch

See Koch. Neues Jahrb. für Mineral. 1881. p. 237, and other German authors

There are a few shells of small size in a quartzite at the above cited locality which are coarse ribbed and hardly to be distinguished



Rensselaeria cf. crassicosta

from specimens of R. crassicosta which I have received from Professor Kayser. The dorsal valves show a long and much thickened septum with a divided hinge plate.

R. crassicosta is from the Taunas quartzite and Siegen beds of the Coblentzian.

Lower Devonic. Misery stream, first dam in town of Sandwich, Me.

Rensselaeria atlantica nov.

Rensselaeria mainensis Williams, U. S. Geol. Sur. Bul. 165. 1900. p. 80, not described or figured.

The Rensselaerias of the Chapman Plantation faunas are of singular interest for the type of structure they present. They occur both in the Presque Isle stream outcrops and at Edmunds Hill but there is a difference in the forms from the two localities which is expressible in terms of development only.

The Chapman Plantation shells have a naviculoid contour, that is, the ventral valve is highly arched and elevated medially, the beak conspicuous and overarching the hinge, the lateral slopes of this

valve abrupt while the dorsal valve is but gently convex, its beak being so depressed that it is obscure and the valve has a shouldered appearance on account of the broad regular convexity across the posterior part, from which there is a gentle slope anteriorly. The marginal outline is subcircular. In the more progressed type expressed in the Presque Isle outcrops the large and thickened hinge plate is fully developed and was completely perforated at maturity. Likewise the strong adductor muscle scars separated vertically by a low septal ridge have quite the expression they display in fully developed specimens of R. ovoides and they even show the peculiar divergent vascular markings over the posterior

Rensselaeria atlantica

slopes which have been heretofore recorded only in a single example of R. ovoides [Pal. N. Y. v. 8, pt 2, pl. 75, fig. 5].

These are structural features important to emphasize for no other species thus far described reproduces these details of that well known Oriskany shell so well. In the ventral valve, also, mature shells bear the expression of R. ovoides in their fully developed dental lamellae and deep pedicle pit. The shells of this species in early stages are transverse or subcircular rather than elongate, the increase of length being an acquisition of later growth. The hinge line is straight and extends for the full diameter of the shell giving the latter a semicircular outline.

On both ventral and dorsal valves a distinct and prominent cardinal area is present. The straight hinge line extending for nearly the entire width of the valve makes this a conspicuous feature, on the dorsal valve the area maintaining its notable width to the extremity of the cardinal line and then quickly losing it on the hinge angles. In the ventral valve this feature is made

more prominent by the greater elevation of the beak and consequent greater width of the area.

To a certain degree this structure is comparable to that observed in the subgenus Beachia H. and C. (type, R. suessana Hall, Oriskany, Cumberland, Md.). In this shell "the cardinal margin beneath the beak [of the ventral valve] is flattened into a well defined pseudoarea" [Pal. N. Y. v. 8, pt 2, p. 259]. Here however is a high development of a cardinal area to a degree far beyond that expressed in Beachia. Furthermore in Beachia "the short inflection of the margin beginning here [on the hinge line] is continued along the lateral portion of the shell where it meets a similar marginal inflection from the opposite valve. These produce the sharp introversion of the lateral margins which is also one of the characteristics of the genus Megalanteris." No such reentrant margins occur in the shells under consideration. I would not refer the species to the subgenus Beachia lest thereby its real affinities be obscured.

The kindness of Prof. E. Kayser of Marburg has enabled me to compare my material with typical examples of the Rensselaerias, R. strigiceps F. Roemer and R. crassicosta (Koch) Kayser, of the lowest arenaceous Devonic of the Rhine, and my lamented friend, the late Dr L. Beushausen of the Landesanstalt, Berlin compared some specimens from the Presque Isle stream fauna with examples of the species mentioned, in the collections of that institution.

The evidence at hand is very clear that while the specimens currently referred to R. strigiceps are quite variable in degree of surface striation, yet this species also bears a cardinal area upon the valves. This feature is particularly well shown by a valve from the Taunus quartzite of Katzenloch near Idar in the Rhine province. In the main the specimens of this species are somewhat more finely striated than those from the Presque Isle but this is a difference notable only in the older shells where by obsolescence of the lateral striae the riblets become apparently less.

An internal cast of R. strigiceps, somewhat distorted, from the Siegen greywacke at the iron mine Alte Mahlscheid near Herdorf illustrates the immature character of certain of the generic structures. Thus the hinge plate and cardinal process are thin and not perforated, the dental plates and pedicle pit rather inconspicuous and the muscular impression not sufficiently strong to eradicate the marks of the shell plications. Such an expression of

these structures is immature in the sense that they characterize this primary manifestation of species of Rensselaeria. This is their expression, for example, among the species of the Helderbergian fauna. On the other hand the Rensselaerias from Presque Isle stream are in these respects up to the full development of the type of the genus, R. ovoides. These characters in such condition do not therefore indicate a primitive phase nor an early stage in the history of the genus.

The shells from Edmunds Hill are of more primitive expression, especially in hinge structure, the plate not being thickened though well developed and separated medially or perforated, in this respect having the structure of the early species of the genus, such as occur in abundance in the beds of the Helderbergian of New York. This shell is in a general way smaller and carries within itself the expression of retarded development with reference to the larger forms at Presque Isle. I will not venture the statement that the small forms do not occur at Presque Isle but the larger have not been observed at Edmunds Hill.

The similarity of these smaller forms with the R. stewarti of Dalhousie is very close yet it seems to me improper to unite the shells, for such union would lead to the identification of the still simpler Dalhousie shell with the progressed form from Presque Isle. At Dalhousie the species seems to have become fixed in its primitive details; conditions in the Chapman Plantation region have permitted progress beyond the expression of R. stewarti.

The especial expression of the generic type of Rensselaeria afforded by these two closely allied species is repeated in the shell R. portlandica Billings from the Square Lake limestone of Maine. The last opportunity which the writer had for critical examination of the type of this species was while studying an extensive series of Rensselaeria and brachiopods allied thereto, in the preparation of *Paleontology of New York*, volume 8, part 2. It was then observed that the species Terebratula gaudryi d'Orbigny, the type of Bayle's genus Trigeria, was probably present in the Oriskany fauna of Maryland. This is a strongly plicated rensselaeroid, throughout of similar aspect to these under consideration save in minor details. To the same group R. portlandica belongs and in the work cited was referred to the genus Trigeria.

The genus Trigeria means a strongly plicated rensselaeroid with the hinge plate in an elemental condition, i. e. perforated, but with cardinal process slightly developed if present at all, and a cardinal area more or less distinctly retained on both valves. The genus

stands to Rensselaeria (R. ovoides) in the relation of a neanic to an ephebic condition. R. atlantica, in its progressed expression even though retaining the primitive structure of the cardinal areas, can not be brought within that group, and Trigeria can not be construed as a valid generic term in the face of the facts here adduced.

In the closest association with the Edmunds Hill and Dalhousie shells are specimens which I have received from Prof. E. Kayser labeled R. strigiceps Roem. from the Siegen greywacke, at Siegen (Coblentzian). Though the shell is persistently smaller than those referred to, it is of the same contour, degree of plication and interior structure, emphasizing again the "Trigeria" characters. Precisely what is the relation of this small form from Siegen to the large, elongate, more characteristic examples of R. strigiceps from the Taunus quartzite at various localities which bears so strong a resemblance to R. atlantica, the writer is not in position to say, but it may prove to be the same as that we have here indicated.

Rensselaeria (Amphigenia) parva nov.

A small, sometimes quite elongate species often presenting the appearance of a miniature of A. elongata Conrad. In the

Rensselaeria (Amphigenia) parva

ventral valve the median septum is strong and the spondylium well developed, the lateral surfaces of the bottom of the valve vascular

or pitted. In the dorsal valve there is a large perforated hinge plate, the foramen apparently always open in contrast to the condition of old specimens of A. elongata. The external surface is marked by rather strong concentric lines with some radial lines along the middle of the valves.

Lower Devonic. Moose river at Stony brook and Moosehead lake, Baker Brook point, Me.

Beachia amplexa nov.

B. suessana and Megalanteris ovalis Hall are two very similar brachiopods in the Oriskany fauna. Whenever a considerable number of specimens of both are available, those of the latter are, as Professor Hall noted in 1859, generally larger, more compressed and proportionally broader. Further differentials are found in the more broadly rounded anterior margin of the latter, the absence of introverted margins except at the cardinal shoulders and a low radial surface striation, coarser but more obscure than in Beachia, and restricted to the marginal regions rather than covering the entire shell as in that genus. The critical distinction in

Beachia amplexa

the genera however is an internal one based on the structure of the cardinal process. These features have been elaborately illustrated by Hall and Clarke[1] whose figures show that in B. suessana this process is distinctly rensselaeroid and consists of two flattened subtriangular plates fused medially and thickened or cushion-shaped at the sides with a median foramen beneath the beak which is closed only by excessive calcification. In M. ovalis this cardinal process is stout, subcylindrical, doubly grooved at the extremity and rising from a flat hinge plate, as though in effect the single cylindrical process were superinduced on the hinge plate of a Beachia.

[1] Pal. N. Y. 1894. v. 8, pt 2, pl. 77.

The shells under present consideration which afford such characters as those specified, are wholesome looking individuals of the aspect of Megalanteris, averaging larger than specimens of either B. suessana or M. ovalis and yet they have a predominant similarity to the latter. They combine however in most instructive manner the characters of both these species and genera, and we endeavor to express this relation by comparison in tabulated form with the distinctive characters of each.

BEACHIA SUESSANA	MEGALANTERIS OVALIS
Outline elongate	*Outline subcircular*
Margins introverted deeply at side and slightly in front	*Margins introverted but slightly at the cardinal shoulders*
Surface finely striated	*Surface smooth* *Coarse internal striations interlocking at front margins*
Shell punctate	*Inner shell layer punctate*
Cardinal plate composed of two cushioned crural bases cemented medially. Foramen usually open except in old stages. No cardinal process	Cardinal plate flat and thickened bearing a stout cylindrical process doubly grooved at the summit. Foramen lost
Ventral adductor scar shallow and faintly defined	*Ventral adductor scar deep, long, sharply divided*
No vascular markings	*Vascular markings*
Dorsal muscle scar extremely faint	*Dorsal muscle scar well defined and clearly divided*

We may fairly summarize the above by the statement that the shells under consideration essentially agree with M. ovalis in all respects save that which has been regarded as the basis of the generic distinction, namely the structure of the hinge plate. Hence the shells are to be referred to Beachia rather than to Megalanteris.

This statement however obscures with words the actual relations. If we analyze the structural features in order of ontogenic values it is evident that M. ovalis simply represents a greatly progressed condition of which Beachia suessana is a prim-

itive expression and that here concerned an intermediate stage. Regarding the last named this condition is evinced in a usually greater thickening of the hinge plate than prevails in Beachia, and a less strong development of the muscular scars than in M. ovalis.

B. suessana is an Oriskany species of the Cumberland basin, Maryland. The specimen which has been identified therewith in the Oriskany at Rondout is familiar to the writer but there is no particular reason for assigning it to Beachia rather than to Megalanteris. The simplest expression of these shells is therefore the most southerly.

For the sake of an expression therefore the term applied to this species will serve. It is evident that the generic distinction between Beachia and Megalanteris is a fugitive one and of little value. Probably it will be found wise to withdraw the former term altogether and express the relations here indicated by specific terms which are even then too exacting. It is not a matter of record that these species have the same character of brachial processes but specimens are before me from the Glenerie Oriskany which show this to be the case.

Lower Devonic. Grande Grève and Percé rock, P. Q.

Megalanteris thunii nov.

Shells having the aspect of M. ovalis Hall often with more convex ventral valve and distinguished chiefly by numerous gen-

Megalanteris thunii

erally fine radial plications covering the entire surface except the umbones. This last feature is highly developed and is not connected by gradation with the smooth exterior of M. ovalis.

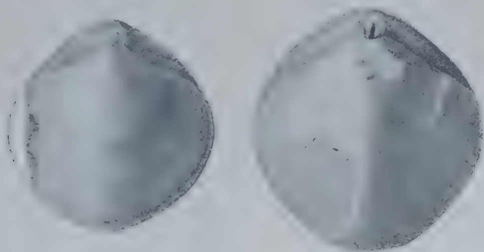
The internal markings are essentially as in the other species, the ventral adductor scar being even more conspicuous, the cardinal plate less developed.

Lower Devonic. Grande Grève and Percé rock, P. Q.

Meristella champlaini nov.

Specimens of Meristella are among the commonest fossils in the Grande Grève limestones. Adult forms of this species share with immature individuals a well defined habit which can be readily distinguished from the known characters of one and another of the many species of the genus which have already been described from the faunas of about this age.

Into immediate comparison with these shells we bring the following known forms: M. laevis, M. arcuata, M. sub-



Meristella champlaini

quadrata of the Helderbergian fauna; M. lata and M. vascularia of the Oriskany fauna. Comparisons therewith are introduced *seriatim*.

Meristella laevis Vanuxem (Atrypa laevis Vanux, Geol. N. Y.: Rep't on Third Dist. 1842. p. 120, fig. 2; Merista laevis Hall, Pal. N. Y. 1859. 3:247, pl. 39, fig. 3, 4; Meristella laevis Hall & Clarke, Pal. N. Y. 1894. v. 8, pt 2, pl. 43, fig. 3-6) is a rather elongate shell with long cardinal slopes making a relatively small angle with each other. Both valves are moderately and subequally convex, the ventral valve faintly sinuate medially in old stages with a broad and rather short linguate extension on the front margin, which when slightly broken, as in most of Hall's figures, gives the front a subtruncate appearance. The dorsal valve has a broadly defined median ridge in all stages, but obscure near the margin in the adult. On the interior there is seldom any trace of vascular impressions departing from the muscular area.

M. champlaini ordinarily has less sloping cardinal margins and it is uniformly a proportionally broader shell. The convexity of the valves is persistently greater and specially so in late stages. Like M. laevis it carries a medial ventral sinus and a dorsal median ridge with depressed lateral slopes, but the linguate extension at the margin is greater. On the interior the vascular markings are highly developed.

M. arcuata Hall [*see* Pal. N. Y. 1859. 3:249, pl. 41, fig. 1a-t; Hall & Clarke, *idem.* 1894. v. 8, pt 2, pl. 43, fig. 1, 2; pl. 44, fig. 5] has a much larger umbonal angle than M. laevis and this is well expressed in M. champlaini. It likewise has the deeper valves of the latter, the ventral being specially curved at the umbo and arched at the beak. Here too we mark the deep lingua on the front margin as large or larger than in the Grande Grève shell. Differences in the two species are obscure but on the whole M. arcuata is less elongate, less sharply ridged on the dorsal valve and the interiors are without vascular markings.

M. subquadrata Hall [*see* Pal. N. Y. 1859. 3:249, pl. 40, fig. 3] expresses a condition in which the form of the shell is squared by the truncation (casual?) of the antelateral margins, making the median dorsal ridge quite prominent, a condition which is sometimes approached accidentally by M. champlaini.

M. lata Hall [Pal. N. Y. 1859. 3:431, pl. 101, fig. 3a-w], an Oriskany shell, differs from M. arcuata chiefly in size and the tendency to acquire a breadth unusual to that species. The prolongation of the anterior margin and the depression of the ventral umbo are also distinctive features and in both of these respects the shell is not the same as that in hand.

M. vascularia (described as M. ? vascularia Clarke, N. Y. State Mus. Mem. 3. 1900. p. 45, pl. 6, fig. 12-14) comprises large shells with the proportions of M. lata but having the pedicle scar greatly developed and bounded by high dental plates, and the large adductor scar common to all these species obscured almost to obliteration by the pallial ridges and sinuses. The latter are here much more highly developed than in M. champlaini where the muscle scar suffers no obscuration therefrom.

M. champlaini is the designation which, in view of the peculiarities mentioned, we propose for the shells under consideration. It serves to express the fact that they share the features of a series of essentially contemporaneous forms in the American province and at the same time combine these in such a way that,

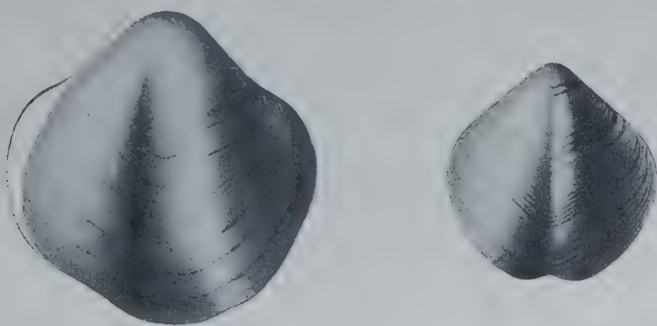
considered ontogenetically, they are always distinguishable from those, while on the whole most nearly allied to the later expressions in the Oriskany sandstone.

Lower Devonic. Grande Grève, P. Q.

Athyris hera nov.

The sandstones at Gaspé Basin afford casts of ventral valves, one of them of noteworthy size, of subcircular outline, considerably arched at the umbo but depressed on the slopes, and with a narrow deep and evenly rounded median sinus; the surface of the valve bears only the concentric lines of growth and very fine radial striae visible only in the sinus. The valve has a length and width of 45 mm.

The larger specimen suggests a Spirifer allied to the rare type of S. laevis of the Ithaca (Portage) fauna of New York, though



Athyris hera

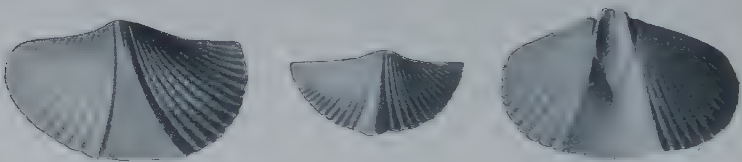
more orbicular and with more pronounced sinus. That species has been regarded as a fimbriated shell, but the fine radial lines of this specimen have less the character of fimbriae than of the lines on S. radiatus Sow. which, without plications, is the starting point of a considerable series of radiate-plicate shells. The general approach of both our specimens to species of Athyris, such as A. spiriferoides of the Hamilton fauna indicates a more probable relation therewith.

Middle Devonic. Gaspé Basin, P. Q.

Spirifer perimele nov.

This is a shell, abundant though poorly preserved in some of the sandstone blocks, which I should identify with S. carinatus Schnur were it not for the presence of fine and crowded lamellae

which cover the surface. S. carinatus has been often described and illustrated from the Coblentzian, most recently by Kayser in *Fauna des Hauptquartzits,* 1889, page 24, plates 1, 10, 14 and Scupin, *Die Spiriferen Deutschlands,* 1900, page 26, plates 2, 3. S. perimele is a shell of medium proportions with relatively narrow cardinal area extending to the full width of the shell; its fold and sinus are conspicuous and rounded, relatively narrow, the fold sometimes becoming angular near the front. There are 10



Spirifer perimele

to 12 rounded, closely appressed plications on each lateral slope, with narrow intervals. The sculpture when well preserved, which is not often, consists of subequidistant concentric elevated lines without trace of radii or fimbriae. The interior of the ventral valve shows a narrow but rather long ovate muscle scar which is not deeply depressed and is bounded by short dental lamellae. Fuller description of the shell can not now be given but these features are sufficient to indicate a dissimilarity with any known American Spirifer of this horizon.

Lower Devonic. Moosehead lake, Baker Brook point, Me.

Spirifer subcuspidatus lateincisus Scupin

Spirifer subcuspidatus var. lateincisa Scupin. Die Spirif. Deutschlands, p. 19, pl. 1, fig. 13, 14. Palaeontolog. Abhandl. 1900. v. 8

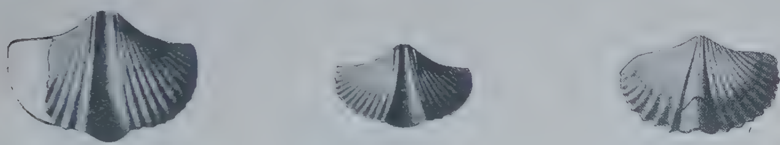
Under this term is separated by the writer quoted, certain shells which have heretofore passed as S. hystericus Schloth., among them those identified by Beushausen from the Spirifer sandstone of the Kahleberg. It is with these shells, many of which were collected by the writer in the Hartz when in company with the late Professor Beushausen, and which are now before me bearing his label, that I undertake to identify the Spirifer prevailing at Presque Isle stream. The critical feature from which the varietal term here used is derived is the long and divergent dental plates of the ventral valve, lateincisus being a term which has no significance in application to the organism but only to its mechanical surroundings. This Spirifer is a form not represented

in the Appalachian Devonic; comparisons therewith are thus needless. Agreement with the specimens from Hahnenklee and Rammelsberg in the Hartz is found in the following particulars:

1 *Size.* The average in this respect is slightly larger for the adult German specimens.

2 *Outline.* The hinge is not extended, and the cardinal angles not produced; less than or equal to 90 degrees. The margins are gently rounded and gradually approximate to the front. The cardinal area is moderately high and slightly curved making an arched ventral valve.

3. *Plication.* The median sinus in each has the width of five to six lateral furrows. The lateral plications are eight to nine on



Spirifer subcuspidatus lateincisus

each side of fold and sinus and they are narrow, round, separated by furrows of similar width. The concentric markings are growth lines which may show a tendency to rugosity near the front.

4 *Fold and sinus.* The sinus is moderately deep and angulated. It is more sharply angulated on the Maine specimens; in some of the German specimens this angulation is apparent only in later growth. The fold is the counterpart of these characters.

5 *Internal characters.* Most notable independently and in point of agreement are the very long dental plates, which diverge rather more in the German than in the American form. In the Hartz specimens these plates lie uniformly in the first radial grooves and hence diverge at the angle of divergence of the radii. In the American shells they are quite as uniformly subparallel to each other and thus are not parallel with the radii but transect the proximal end of first sulcus and plication. This is a slight but persistent difference. The muscle area in both shells is but faintly defined on the ventral valve.

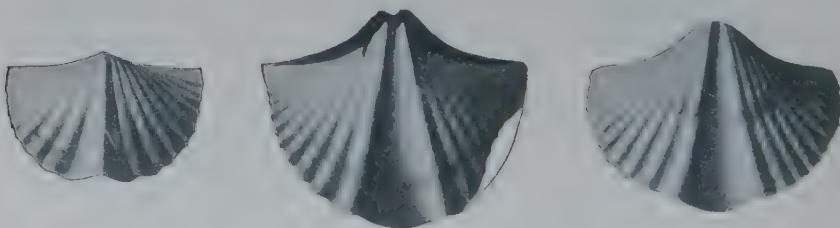
Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

Spirifer cymindis nov.

This is a shell belonging to an extensive group of early Devonic species which I presume are all minutely fimbriate (as in S. concinnus Hall) though not in all have the surface characters been

fully determined. Distinctions are refined in this series of fossils and the differentials of the shell before us can best be indicated by comparisons with other members of this series.

In a general way, however, it may be said that S. cymindis is a shell of larger size and stouter proportions than S. subcuspidatus lateincisus of the Presque Isle outcrops. The form is short-winged with a prominent and arched ventral beak, well developed subangular median sinus and fold, the width of the former equaling the distance between three to four radial furrows; of the latter that of three plications. Both sinus and fold have abruptly sloping sides and a narrow bottom and top. The primary plications are conspicuous by their elevation beyond the rest. The radial plications are rounded on the exterior with sharp and narrow furrows, sharper on the internal cast with broader furrows.



Spirifer cymindis

There are seven to eight plications on each lateral slope. In rare instances there is a faint median plication in the sinus. Fine concentric growth lines with traces of fimbriae cover the surface.

The dental lamellae are short divergent and inconspicuous, the muscle scar of the ventral valve small, well defined, deeply divided by the median sinus. The shell is not greatly thickened about this area and the inner surface adjoining is rarely pustulose.

Comparisons. S. concinnus Hall. In this Helderbergian form we have a shell of like proportions but with much more elevated ventral beak and broader cardinal area, more abundant plication, 10 to 12, greater width of fold and sinus and extended projection of the sinus on the anterior margin.

I am here again indebted to Professor Kayser and Dr Drevermann for affording facilities and suggestion for comparison with European species of the early Devonic.

S. arduennensis Schnur [*see* Schnur. Brachiopoden der Eifel; Palaeontographica. 1854. 3:199, pl. 32, fig. 3; Kayser, Fauna des Hauptquartz. 1889. p. 33, pl. 2, fig. 1-4; pl. 9, fig. 3; pl. 12, fig. 5; pl. 16, fig. 1-9].

This species with which I was at first disposed to identify the shells in hand is usually of small extended form with a very regularly convex ventral valve and broadly rounded plications. Though distinct in outline and contour it often represents the aspect in external and internal surface of S. cymindis.

S. decheni Kayser [*see* Kayser. Fauna d. aeltest. Devon-Ablag. des Harzes. 1878. p. 165, pl. 22, fig. 1, 2].

This is a very large species but its smaller expressions, of which I have specimens from the Kellerswald, are like S. cymindis in degree of plication, though here it is the second rather than the first pair of lateral plications that dominate the rest. The ventral valve is uniformly convex but the umbo is not strongly arched.

S. nerei Barrande [as identified by Walther].

Specimens from the upper Coblentzian of Marburg very like this shell in general aspect are somewhat more numerously plicated but a distinctive feature lies in the very long dental plates such as are present in S. lateincisus.

Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

Spirifer cymindis var. sparsa nov.

Associated with S. cymindis and quite as abundant, is a shell distinguished in gross by its sparser plication. Our material here

Spirifer cymindis var. sparsa

presents us chiefly with a series of internal casts in which there are some differences of expression, noted in particular in the following enumeration:

1 *Size.* The shells are of medium size, uniformly approaching S. arduennensis and S. cymindis in dimensions. Differences in size and age are expressed on the internal cast by a clearer definition in the younger and thinner shelled examples.

2 *Outline and contour.* The marginal outline is subtriangular, the hinge being long and sometimes extended at the angles, the

lateral margins rather directly convergent. The ventral valve is elevated at the beak, the cardinal area being rather high and curved, and the median part of the shell elevated.

3 *Surface.* The median sinus has a width of from two to two and five tenths lateral furrows, its sides being highly divergent, sloping abruptly to the bottom whch is sometimes quite sharp. The primary plications are conspicuous and elevated. On the sides there are four, rarely five, plications, in extreme cases greatly subordinated to the median ones and separated by broad furrows. The sculpture of the surface consists of rather coarse and moderately distant concentric lines which may become lamellose.

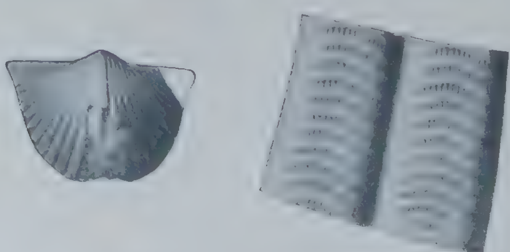
4 *Interior.* The dental plates are as in S. cymindis. The muscle scar of the ventral valve is deeply impressed and sharply defined, specially in old shells where the test is thickened in the umbonal region. The removal of this thickened shell leaves internal casts with a prominent muscle area, the surfaces adjoining which are pustulose. There is no median septum in this valve. In young shells the ribs are sharp on the internal cast but are rounder on old shells.

The features here summarized constitute an expression not represented in the Appalachian faunas and so far as we can ascertain not exactly reproduced in the Coblentzian.

Lower Devonic. Presque Isle stream, Chapman Plantation, Me.

Spirifer aroostookensis nov.

This shell is characterized by its broad, flat ribs with very narrow, radial furrows, in which respect it is remarkably similar to



Spirifer aroostookensis

S. mesastrialis Hall of the Upper Devonic (Ithaca group) of New York. Of these lateral ribs there are 10 to 12 on each

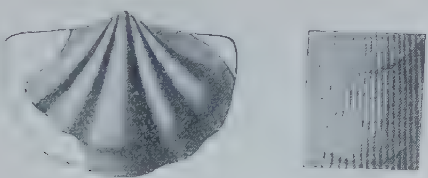
side and each of the large ones bears a slight furrow along its flat top. The median fold is relatively narrow and not highly elevated. The shell is short-hinged and rotund in form. The surface is covered with close concentric fimbriate lines which bend backward at the middle of each sulcated rib. I have seen but a single dorsal valve of this interesting species but its differential characters are very distinct.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Spirifer macropleuroides nov.

The Chapman Plantation fauna carries a representative of the Radiati or group of Spirifer plicatellus in a species which has the aspect of a small Sp. macropleura Conrad,[1] an extreme expression of the form presented by S. togatus Barrande and variety subsinuata A. Roemer[2]; the first from the New Scotland Helderbergian of New York and the others from the lowest Devonic of the Hartz and Bohemia.

In S. macropleuroides the shell is more sharply plicate than in the others, the plications being two or three in number



Spirifer macropleuroides

on each side of the median fold or sinus. Neither of the latter is extremely developed, being broad and regularly rounded; the lateral plications are strong and broad, evenly rounded and with narrow grooves. The surface is covered with very fine longitudinal striae. The shell is distinct from S. macropleura in its smaller size and stronger plications, in which respect it is the most progressed of all the three forms above mentioned.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

[1] Hall. Pal. N. Y. 3:302, pl. 27, fig. 1a-p; pl. 28, fig. 8a-d. Hall & Clarke. *ibid.* v. 8, pt 2 pl. 21, fig. 22-24, 27.
[2] Kayser. Aelt. Devon-Ablag. d. Harzes. pl. 21, fig. 3 and fig. 1, 2, 7.

Spirifer primaevus Steininger var. atlanticus nov.

For comparison consult:

Morris & Sharpe. Geol. Soc. Quar. Jour. 1846. 2: 276, pl. 11, fig. 3. (S. orbignyi)

Steininger. Geognos. Beschreib. der Eifel, 1853. p. 72, pl. 6, fig. 1. (S. primaevus)

Sharpe. Geol. Soc. Lond. Trans. 1856. Ser. 2, 7: 206, pl. 26, fig. 1, 2, 5. (S. antarcticus)

Hall. Palaeontology of New York. 1859. 3: 422, pl. 97. (S. arrectus)

Kayser. Fauna der aeltest. Devon-Ablagerungen des Harzes. 1878. p. 165, 168, pl. 22, 23, 35. (S. decheni, S. hercyniae, S. primaevus)

Ulrich. Neues Jahrb. für Mineral. Beil. Bnd. 8. 1893. p. 65, pl. 4, fig. 19, 20. (S. chuquisaca)

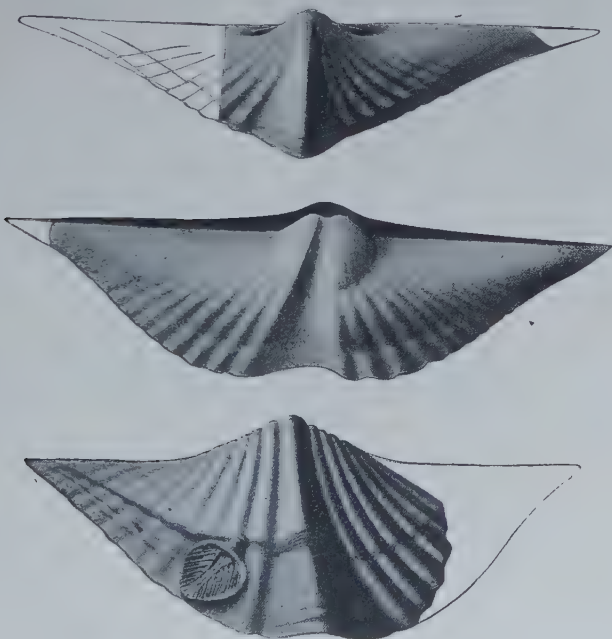
Scupin. Die Spiriferen Deutschlands. 1900. p. 84-88, pl. 8. (S. primaevus, S. fallax Giebel,=S. decheni Kayser, S. hercyniae Giebel. S. hercyniae var. primaeviformis)

Clarke. N. Y. State Mus. Mem. 3. p. 46, pl. 6, fig. 26, 30. (S. murchisoni Orbigny)

Reed. An. South African Mus. 1903. v. 4, pt 3, 7, p. 180, pl. 22, fig. 4. (S. orbignyi Morris & Sharpe)

The identity of species in the group represented by S. arrectus (S. murchisoni) and S. primaevus, is involved with obscurities of a kind which seem to indicate that in the considerable variety of species names from many countries some are synonymous terms and the majority, perhaps all the rest, are local expressions. The general type of structure is that of a sparsely ribbed Spirifer with the plications usually broadly rounded, a prominent fold and sinus without plication in the latter and the entire surface finely fimbriate. The interior of the ventral valve has a very strong muscular scar appearing in the cast as a sulcate cordiform prominence and the plications lose themselves posteriorly on account of umbonal thickening of the valve. The shells now before us from central Maine are identified as a variety of the widely diffused Coblentzian species S. primaevus, not because of structural resemblances that can be fixed upon from the descriptions given of that species and its close allies in the Coblentzian, S. decheni, S. hercyniae and its variety primaeviformis, but the determination is based on comparisons with specimens of these species from Stadtfeld, Kellerwald and elsewhere kindly supplied and identified by Prof. E. Kayser. These shells are of large size with subtriangular outline, the anterolateral margins being

rather direct and not convex. Usually they are of considerable length fore and aft but specimens are found showing no apparent distortion that are quite narrow and elongate. The hinge is the longest measurement of the shell and the ribs number from 7 to 11 on each lateral slope, the smaller number prevailing in the usual preservation. It may be noted that the first pair of ribs bounding the sinus is the highest as this is in contrast to some specimens of the New York Oriskany classed as S. murchisoni, where



Spirifer primaevus var. atlanticus

the first pair is lower than the second. A comparison of these specimens with those referred to S. arrectus of the Oriskany by Hall and well illustrated in the work cited, shows that there is a close approach in structure among the larger forms of those. In a previous publication [N. Y. State Mus. Mem. *op. cit.*] I have referred to the probability that the S. murchisoni of the New York Oriskany is an unstable form putting on the aspect now of one and now of another species elsewhere localized. Scupin has with more detail pointed out this condition suggesting that some of Hall's drawings are of forms equivalent to S. antarcticus, S. chuquisaca, S. orbignyi and S. capensis,

from the Falkland Islands, Bolivia and South Africa and that others, principally the smaller forms express the local value of S. murchisoni. There are excellent reasons for these views, and though shells like S. primaevus var. atlanticus are apparently absent from the New York province yet there is no wide divergence between them and the larger examples of S. murchisoni. It will be understood that a proper interpretation of the congeries passing as S. murchisoni in the Oriskany is possible only in terms of well defined localized expressions.

Lower Devonic. Baker Brook point, Moosehead lake, Me.

Cyrtina chalazia nov.

We are presented in these shells with a departure from the usual aspect of the Devonic Cyrtinas. They are mostly multiplicate shells and in the early stages of this time conform quite generally to the same expression in contour, size and ribbing. Here we have a pauciplicate shell, the dorsal valve of which presents the characters

Cyrtina chalazia

which we have noticed as a feature of Spirifer plicatus of the Grande Grève limestones; few, broad and blunt ribs. The shells are of the small size quite characteristic of the genus with trihedral form and erect or but very slightly curved cardinal area, flat dorsal valve, median sinus and fold well developed, the former having the width of the next two adjoining lateral plications. There are four to five plications on each ventrolateral slope and three to four on the dorsal, the ones nearest the hinge being always very faint. These are in the main broad and smooth and concentric growth lines are usually crowded near the front margin.

Lower Devonic. Dalhousie, N. B.

Trematospira perforata Hall var. atlantica nov.

Species of Trematospira are almost exclusively of Helderbergian age and the species described are pretty well defined on the basis of their sculpture. In the form before us we have one more nearly

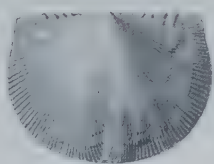
allied in this respect to T. perforata Hall than to any other though it differs substantially even from that. This shell has the following characters: The ventral sinus is not bounded by the median primary pair of plications but by the primary pair just outside the median, the latter in later growth making a pair on the slopes of the wall of the sinus. Likewise the median rib on the dorsal valve, while constituting the crest of the median fold is accompanied by a pair of ribs of primary age which modify the slopes of the fold. At the beak and continuing for one third the length of the shell without modification the number of plications on the ventral valve is 12, on the dorsal valve 11. From this point outward the ribs irregularly dichotomize into two or sometimes three, fold and sinus being affected like the rest of the surface.

The shell is transverse with straight hinge and without cardinal areas. The ventral beak is abruptly perforate and the shell substance punctate.

Lower Devonic. Dalhousie, N. B.

Chonetes impensus nov.

A large shell having the aspect of Leptostrophia oriskania but with coarser striae. The single specimen observed of this species is a ventral valve, regularly convex, with very fine sub-



Chonetes impensus

equal striae for about one half its length followed beyond a distinct growth line by much coarser striae. Hinge margin cornute, Hight 21 mm, length 28 mm. Specifically unlike any form known to the writer.

Lower Devonic. Moosehead lake, 7 miles north of Kineo, Me.

Chonetes nectus nov.

A small coarse ribbed species, transversely elongate in form and having 14 to 16 striae, each of the larger of which is divided at variable distances from the middle to the margin of the valve. It is but slightly convex compared with C. hudsonicus Clarke

and does not attain a length of more than 11 mm. A peculiar feature of the species is the general prevalence of a deep con-

Chonetes nectus

centric constriction in the ventral valve which is present in every such valve yet recognized.

The interior of the dorsal valve is highly radio-pustulate, there being two strong central diverging ribs traversing the valve.

Lower Devonic. Misery Stream, first dam in town of Sandwich; Moose river at Stony brook, Me.

Chonetes aroostookensis nov.

Shell transversely subrectangular, length to width as two to three, hinge line straight, making almost the full width of the shell; cardinal angles 90 degrees or a little more, the lateral mar-

Chonetes aroostookensis

gins expanding gently outward for a very short distance; lateral margins direct at first then broadly curved to the anterior margin which is transverse. Ventral valve gently and quite uniformly convex, somewhat depressed to the cardinal angles. Cardinal area

carrying a row of spines, five in number on each side of the beak, the outer ones attaining considerable length. Surface markings consisting of fine threadlike radii increasing rapidly by bifurcation, the striae and intervening grooves being of subequal size. There are three or four of these in 1 mm. A notable feature is the predominant size of the median stria on this valve. There are also suggestions of concentric or oblique undulation near the cardinal extremities. The surface sometimes shows a broad undefined depression with others at the side which may produce a gently undulated surface. This, however, is not a persistent feature. The dorsal valve is concave and on the interior shows a small bifurcate cardinal process flush with the cardinal area. The sockets and socket walls rest on a greatly thickened ridge just within the hinge line and subparallel to it. This notable ridge has an abrupt posterior slope leading down to the muscular area which is divided by three short and divergent ridges.

Dimensions. The average example has a length of 16 mm, width of 23 mm.

In seeking comparison of this very well defined species with allied forms we may note the following:

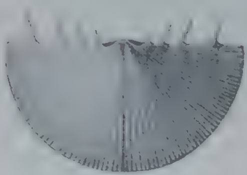
With Chonetes canadensis Billings of the Grande Grève fauna, it is more closely related than with any other, in outline and proportions. Like that it carries a conspicuous median stria. But the species are not to be confounded; C. aroostookensis is a stouter and heavier shell with a much coarser surface striation and a more convex ventral valve. It is less delicate and tenuous and never attains the notable dimensions of that species. With C. nova-scoticus Hall from the Arisaig series of Nova Scotia, it agrees in the development of the median stria but the resemblance there ceases. Chonetes latus v. Buch as identified by Sowerby from the Tilestones of Horeb Chapel, with which it has been compared, has not even remote relation with it. Davidson long ago pointed out that most of the Silurian Chonetes which had been referred to C. latus are identical with C. striatellus Dalman but he specially excepted the forms from Horeb Chapel. Neither the one nor the other presents any features for comparison here, the Tilestones shell being small, convex and minutely striate. C. sarcinulatus Schloth., from the Spiriferensandstein and other horizons of the Coblentzian is somewhat similar in form but is more evenly striate, without large median stria and is notably convex. Schnur's variety of this species, planus, from the same beds is little known but appears to be a shell of less width.

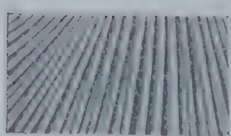
Of all the species of early Devonic age C. falklandicus, Morris and Sharpe[1] presents the closest similarity though of smaller size and rather less subrectangular outline. One might with reason regard the Aroostook species a varietal expression of C. falklandicus. This species has been recently identified in the Bokkeveld beds of Cape Colony and figured by Reed[2] and these figures also show a narrower shell than that under discussion though attaining its full dimensions.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Chonetes paucistria nov.

This is a rare shell associated with the foregoing, distinguished therefrom by the fewer and coarser striae, barely more than one half the number in C. aroostookensis, increase therein aris-





Chonetes paucistria

ing from implantation near the margins. The outline also is not subrectangular but subelliptical, the greatest width at the hinge and the margins converging quite rapidly in a broad curve. These differences are expressed in our figures.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

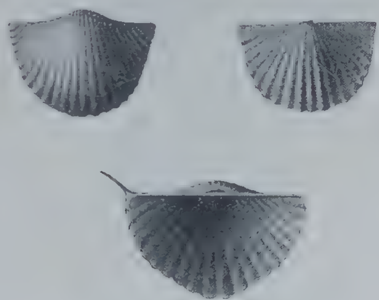
Chonetes billingsi nov.

Chonetes laticosta (Hall) Billings. Palaeozoic Fossils. 1874. v. 2, pt 1, p. 20

These shells are characterized by the high gibbosity of the central region and abrupt slopes to the margins in the pedicle valve and the coarse rounded ribs separated by interspaces of about the same width. The ribs are usually simple, extending from beak

[1] Geol. Soc. Quar. Jour. 1846. 2: 274, pl. 10, fig. 4.
[2] An. South African Mus. 1903. v. 4, pt 3, p. 169, pl. 20, fig. 9, 10.

to margin and number from 16 or less in small individuals to 26 in the largest shells seen. In full growth of the shell the median rib becomes more pronounced than the rest on the anterior margin and thus makes a low median angle at this margin. Extremely fine concentric lines are visible under favorable preservation. The cardinal area is narrow and only in rare instances are spines retained or developed at the cardinal extremities. On the interior the brachial valve has a small erect V-shaped cardinal process and short thin outer socket walls. On each of the simple coarse ribs which correspond to the furrows of the exterior is a single row of sharp pustules the median row being the most depressed, and the two adjoining the most prominent. No trace of reniform or other lateral depressions is evident. In all such small and coarse ribbed species represented by C. billingsi, C. laticosta Hall and



Chonetes billingsi

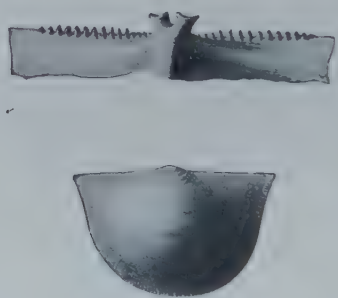
C. mucronatus Hall, there is a natural similarity of expression extending even to the interior characters of the brachial valve, but the distinctive differences of C. billingsi consist in its gibbosity, angulated front margin at maturity, stronger, coarser and more uniformly simple ribs. In respect to these characters in all the shells they are the most pronounced in that before us and become progressively decreased in the upward range of the group, so that it serves the purposes not only of paleontologic but also of geographic distinction to recognize distinctively this early manifestation of features which are less pronounced in C. laticosta of the Onondaga limestone and still further diminished in C. mucronatus of the Marcellus and Hamilton.

Dimensions. A full sized example has a width on the hinge of 13 mm and a length of 11 mm. From this the size ranges downward to a length of 2 mm.

Lower Devonic. Grande Grève, P. Q.
Middle Devonic. Gaspé Basin, P. Q.

Stropheodonta hunti nov.

Shell small, regularly convexo-concave. Ventral valve most convex along the median line, where the curvature is evenly arched and well elevated; lateral slopes depressed, at times slightly concave. Hinge line long, straight, often with cardinal extensions; the length of hinge is to the length of shell as three to two. The surface of the valve is uniformly smooth, usually appearing nacreous and without lineation but well preserved exteriors show an extremely fine radial striation hardly visible to the naked eye. About the umbo are a few low corrugations, three or four in num-



Stropheodonta hunti

ber and these become extinct over the body of the valve. The dorsal valve shows the same degree of corrugation as the ventral and cardinal area of conjoined valves indicates nearly complete closure of the delthyrium and a fine denticulation extending almost to the cardinal angles. The species has been observed frequently.

The shell suggests both in size and in the aspect of its nacreous surface the well known S. nacrea from the Hamilton of New York[1] for which Hall and Clarke introduced the subgeneric term Pholidostrophia.[2] Other representatives of this group are known, namely an undescribed shell from the Onondaga limestone of New York and Ohio and probably the Strophomena lepis Bronn of the Eifel Middle Devonic.

Lower Devonic. Grande Grève, P. Q.

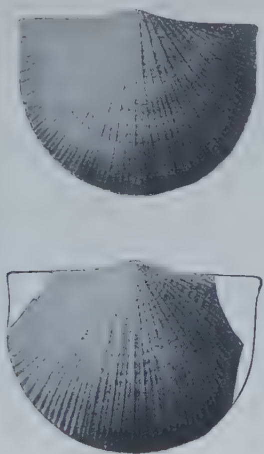
[1] According to Schuchert this is the same shell as that described by Owen as Chonetes? iowensis from the Middle Devonic of Iowa and if this is the older species name it should take precedence

[2] Palaeontology of New York, 1892, v. 8, pt 1, p. 287.

Stropheodonta patersoni Hall protype **praecedens** nov.

See S. patersoni Hall and S. inequiradiata Hall. Palaeontology of New York. 1867. 4: 87, 90

Professor Hall noted in his description of the two species cited above, both from the Schoharie grit and Onondaga limestone that while in normal forms distinction is readily made, many shades of transition in style of surface sculpture are found. The shells are both regularly convexo-concave species with denticulate hinge with the surface ornament fundamentally consisting of fine elevated and fasciculate striae, each pair of larger ones including 6 to 10 finer, multiplication of the larger consisting in the superior development of the median stria in the fascicle. These lines are finely



Stropheodonta patersoni protype praecedens

reticulated by concentric elevated striae. Superinduced on this ornament are, as a species character in S. patersoni, concentric discontinuous corrugations affecting chiefly the intervals between the primary striae. These occur faintly and sporadically in S. inequiradiata. Billings figures [Palaeoz. Foss. pl. 2, fig. 3] from division 1 of the Gaspé series, between Cape Rosier and Grande Grève a specimen identified as S. varistriata Conrad in which such corrugated exterior is present, and we have already commented on this structure. He also insists that there is no distinction between this shell (and species) and S. inequiradiata except that the former is of smaller size. Comparison of typical material representing these species however demonstrates that notwithstanding the common possession of the cor-

rugations, S. varistriata is not only smaller but more nearly square in outline with nearly rectangular cardinal angles (S. rectilateralis being one of Conrad's synonyms) while in the other species the outline is more elongate, semielliptical, the lateral and anterior margins form a continuous easy curvature and the cardinal angles are more acutely rounded. These differences produce a notable distinction in the general habit of the species. The Grande Grève limestone shells palpably express the characters of S. inequiradiata and S. patersoni; but in so far as differences in these two are concerned it is to be noted that in the former the fasciculation is best expressed over the middle parts of the shells, but in later growth about the periphery this fasciculation gradually becomes lost or passes into an irregularly unequal striation. The corrugations are restricted to the fasciculate area.

S. patersoni, holding its fasciculate character throughout growth, is in an arrested condition with reference to this species. The Grande Grève shells seem rarely to pass the stage in which the fasciculation of the striae is obscured as in S. inequiradiata but neither do they always present the corrugations of S. patersoni. These corrugations are usually present, sometimes very strongly developed, again obscure, but they may be altogether absent leaving the simply fasciculate exterior so prevalent in the Strophomenidae throughout their history. In view of these facts we prefer to designate the Grande Grève shells as a variation or protype of S. patersoni.

Dimensions. Fully developed examples attain a length of 25 mm and a width on the hinge of 40 mm.

Lower Devonic. Grande Grève, Indian Cove and Little Gaspé, P. Q.

Stropheodonta patersoni Hall protype **bonamica** nov.

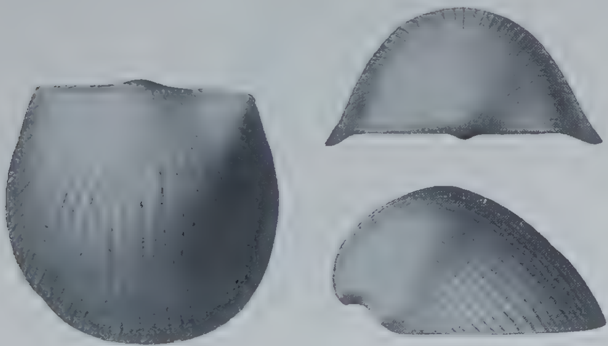
We have noted the difference in the Grande Grève form of S. patersoni and the typical expression of the species in the Onondaga limestone of New York. In the shell before us we have a quite different expression of this type, rare in American waters. The type itself, we may briefly reiterate, is expressed in the highly convex form, the strong fasciculation of the striae and the corrugation of the umbonal portion of the valves. We are here presented by a relatively small and quite narrow shell with a short, straight hinge, prominent cardinal extremities, highly convex or gibbous curvature (ventral valve) and greatly produced

anterior margin. These are distinctly mutational characters which constitute very notable differences in the shells. The surface characters are more distinctly indicative of progressional phases of development and may be thus tabulated for the three different expressions of the species:

Primary fascicles at the beak
- 19–25 patersoni
- 10–14 precedens, bonamica

Intercalation of striae apicad of summit
- frequent—precedens
- less frequent—patersoni
- occasional—bonamica

Anterior slope
- finely and subequally lobed—patersoni, precedens
- coarsely and strongly fasciculate—bonamica



Stropheodonta patersoni protype bonamica

The umbonal corrugation appears to be differently developed according to individuals, but generally is coarsest in precedens, smaller and more numerous in patersoni. The summarized evidence indicates the phylogenetic relation of these species to be thus: bonamica retains the most primitive expression throughout supplemented by the character of its hinge which is denticulate only near the delthyrium; precedens is still more primitive than patersoni in respect to striation, but less so than bonamica. The relation indicated seems to be in accordance with the actual time relations of these shells.

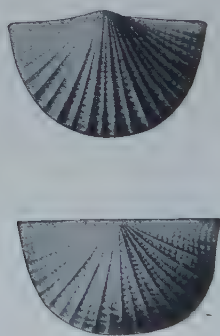
Students of the Brachiopoda recognize in the fasciculate-crenulate type of surface structure a recrudescence in these early Devonic shells of characters which appeared among the Strophomenoids in the Lower Siluric and except for the crenulation became prevalent. This later expression is never common nor did

it last long. The typical S. (Orthis) interstriatus Phillips is shown by Davidson[1] to carry at times the umbonal crenulations and the large and fine S. nobilis McCoy[2] exemplifies both characters in very simple expression, both of these species being recognized as of Middle Devonic age. The former species is commonly regarded as present in the Eifelian.

Lower Devonic. Dalhousie, N. B.

Stropheodonta rosieri nov.

This is a small shell characterized by its simple, relatively coarse and highly angular plications which increase by implantation starting with 8 to 10 at the beak and becoming twice that number at the margin. Over these and in the intervals are fine radiating



Stropheodonta rosieri

surface lines. The umbonal region is crenulated by undulating concentric lines which may sometimes extend over the whole surface. The shells have thus some of the characters of S. patersoni precedens of the Grande Grève limestones and of those known in the New York rocks as S. varistriata, but the divergence from either is apparently fixed.

Lower Devonic. St. Alban beds, Cape Rosier Cove, P. Q.

Stropheodonta crebristriata Conrad (Hall) protype **simplex** nov.

See Hall. Palaeontology of New York. 1867. 4:86, pl. 11, fig. 12, 13, 18-21

On comparing with the hypotypes of this species illustrated in the work cited, a few shells from Grande Grève, we observe that

[1] Monogr. Brach. 85, pl. 18, fig. 15-18.
[2] *idem.* p. 86, pl. 18, fig. 19-21.

the young condition of S. crebristriata (a Schoharie grit species in New York) represented by the original of plate 11, figure 13 [*op. cit.*] corresponds remarkably in size, contour and surface with these. The shells in hand are quite regularly convex having the greatest width along the hinge, a semielliptical marginal outline and the surface bears 8 to 10 sharp angular but not elevated plications, which increase in number by implantation so that the margin bears at least four times as many plications as the beak. In S. crebristriata, as referred to, there are about the same number of plications though they are individually less prominent and their duplication begins somewhat earlier. This specimen shows a fine interlineation which we observe only at the margin of the Gaspé shell.

We construe this shell as a simple and early expression of S. crebristriata, probably not attaining greater size or more progressed development in surface feature than expressed in our specimens.

Dimensions. Length, 13 mm; width on hinge, 16 mm.

Lower Devonic. Grande Grève, P. Q.

Stropheodonta parva Hall protype **avita** nov.

See Hall. Palaeontology of New York. 1859. 4: 85, pl. 11, fig. 5, 11

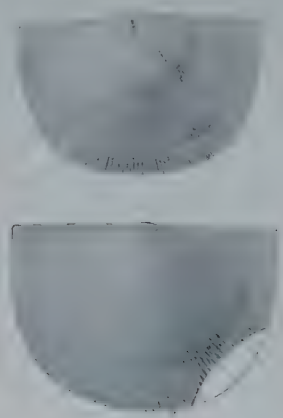
Several brachial valves show at first the median groove and four to five simple strong ribs on each side, such as characterize S. galeata Billings and change this expression by the simple bifurcation of these ribs at about one half their length, and, close upon the margin, by the subdivision of one or the other of these branches. This is the character of S. parva Hall of the Schoharie grit of New York, a rare species, and comparison of the Gaspé shell with the single exterior of the brachial valve figured or known [*op. cit.* pl. 11, fig. 5] shows similarity of dimensions to be accompanied with the like character of surface. In S. parva the ribs are not so strong and bifurcation begins sooner, that is, the period of simplicity continues longer in the Gaspé shell and hence gives it more primitive expression, in accordance with its antecedent date.

Lower Devonic. Indian Cove, Gaspé, P. Q.

Leptostrophia tardifi nov.

Shell of uniformly medium size, averaging about that of L. perplana (Conrad); flat or broadly convex in the umbonal

region, hinge line straight and not extended, commissural margin subcircular. Surface radii numerous, composed of rounded lines with very narrow interspaces, the former increasing quite irregularly by bifurcation but keeping a subequal appearance throughout. The surface seems to have been early subject to irregular growth



Leptostrophia tardifi

from injury or pathologic condition of the mantle, rapid duplication of the striae following each of these cicatrices. These striae are covered by extremely fine concentric lines. Attention is directed to the differing expressions of the surface markings on these allied species, L. tullia Billings, L. magnifica Hall, L. irene Billings and L. tardifi.

Dimensions. Average specimen 35 mm in width on the hinge, length 25 mm.

Lower Devonic. Percé rock, P. Q.

Leptostrophia magnifica Hall protype **parva** nov.

This shell may be best expressed in terms of the widespread L. perplana Conrad and L. blainvillii Billings, for it approaches these in all general features. Analysis of its structural details however shows:

1 The surface striae, fine, threadlike and crowded, exhibit some diversity of size in early growth and this becomes intensified later so that about the margins there is either an inclination to irregular swelling or to fasciculation, the latter at times being quite pro-

nounced. These are characters of L. magnifica not of L. perplana. Concentric wrinkles on the shell are altogether absent.

2 The cardinal area is denticulate to its extremities though narrow and but slightly cross striated; the delthyrium is open.

3 The muscle scars are not greatly divergent but, as in L. magnifica, are contracted at the beginning though they extend more than halfway across the shell.

The shell is essentially a diminutive expression of that species, its fundamental structure being quite in harmony with it and its

Leptostrophia magnifica protype parva

lesser variety tardifi from the Percé rock. In our material an occasional specimen indicates the presence of individuals larger than these we have figured. Dr Drevermann, after examination of these specimens, finds this shell closely approaching L. explanata Sowerby of the Coblentzian though that shell attains more nearly the dimensions of L. magnifica and has flatter rather than threadlike striae on the surface.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Strophonella (Amphistrophia) continens nov.

Strophomena punctulifera Conrad, var. Billings. Palaeoz. Foss. 1874. v. 2, pt 1, p. 32

Shell rather strongly concavo-convex, the normal convexity of the ventral valve being continued for about one third the length of the shell. The reversal is gradual but becomes abrupt specially

in final stages. The hinge line is straight and the cardinal angles very slightly extended, subangular or even rounded; cardinal area narrow, not striated vertically, denticulate but slightly and only near the delthyrium of the ventral valve. The opposite valve receives this denticulate edge in a narrow crenulated groove. The muscle scar of the ventral valve is short and broadly flabellate with somewhat thickened and elevated margins. The deltidium is usually but partially developed. In the brachial valve the cardinal process is strongly bifid, the separate parts being widely separated; dental sockets shallow.

The surface of the valves is marked in the umbonal region by 16 to 20 sharp angular plications, simple throughout the normal contour of the valves. These primary plications with those of the secondary series eventually constitute over the body of the

Strophonella (Amphistrophia) continens

shell a series of fine threadlike lines separated by flat spaces in which lie fascicles of lesser order, sometimes but a single series consisting of six or more lines, sometimes three or more subordinate series. The general expression of the surface ornament however is that of fine sharply fasciculate striation. On the interior of the valves the surface is highly pustulose throughout except on the muscle areas, the pustules being arranged in radial rows.

These are the usual characters of the adult shell. The young of the species are readily recognized as normally convex shells with sharp and strong plications and this is a condition which when maintained to maturity is expressed in such species as Stropheodonta arata of the Schoharie grit of New York.

Variant 1 equiplicata. We find a few of these forms in which the simple sharp plication of growth is not broken up into fascicles but continues sharp over the body of the shell with very sparse intercalations, so that the surface conveys the expression of subequal plication and not of fasciculation. Such forms are at once distinguished by their exterior. The initial striae are a

few more in number than in the normal of the species, but the variation may be interpreted as one due to the protracted continuity of the simple plicated condition of infancy.

Variant 2 senilis. Occasional expressions occur in which the fasciculation becomes well pronounced as a secondary condition following the sharp plication of early growth but finally is obscured or lost by rapid intercalation so that the peripheral surface carries a great number of fine subequal radii. This expression doubtless represents the extreme development of the specific characters beyond the point usually attained in the normal growth of the species.

Variant 3 equalis. Again, in certain full grown shells the primitive coarsely plicate stage is so early suppressed as to be scarcely noticeable and fasciculation is at once inaugurated and continued throughout the shell growth. This is a very early assumption of mature characters unaccompanied by evidences of senile growth in final stages.

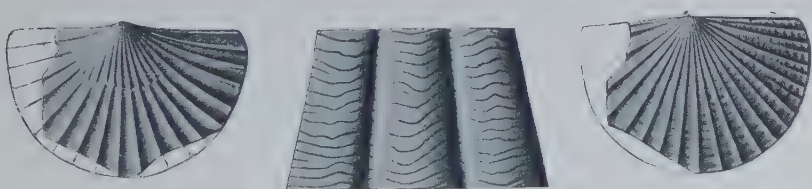
Lower Devonic. Grande Grève, P. Q.

GASPESIA gen. nov.

Gaspesia aurelia Billings *sp.*

Orthis aurelia Billings. Palaeoz. Foss. 1874. v. 2, pt 1, p. 34, pl. 3, fig. 3

The singular valves which Mr Billings described under the name cited are strophomenoidlike shells with straight hinge extending the full width of the valves, central beak, which is slightly produced beyond the hinge line, a generally semielliptical outline, and the surface marked by sharp distant and sparse radial ribs. The



Gaspesia aurelia

substance of the shell is tenuous and none of the specimens shows any trace of hinge structures or muscle scars and none were noted by Billings. Billings remarked that the shell "closely resembles O. pectinella Conrad of the Trenton limestone." In the apparent suppression of hinge structure we have suspected the affiliation of this species with the nearly symmetrical and thin-

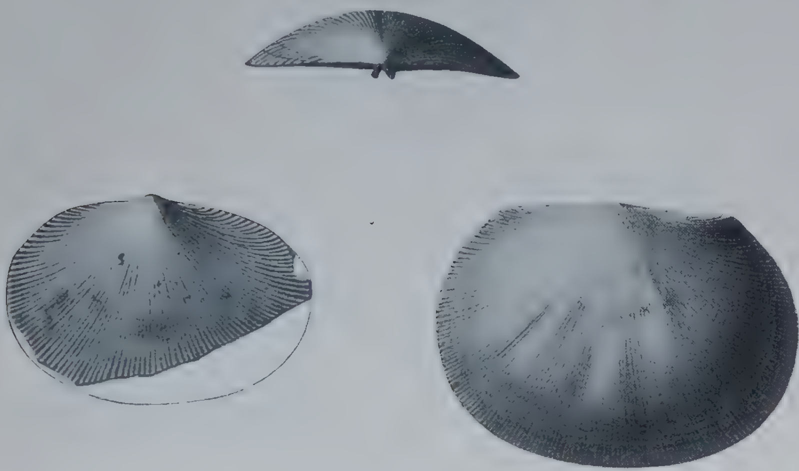
shelled lamellibranchs of the genera Halobia and Daonella and yet there is no positive evidence that the beaks are not axial nor of any specialized anterior part which can be construed as an auricle. They are probably to be regarded as an aberrant strophomenoid, slightly convexo-concave, but the character of the shells is so peculiar as to prevent their admission to any of the recognized brachiopod genera. The strongly ribbed surface bears from 20 to 25 narrow radial plications separated by broad flat sulci which in old shells may show traces of intercalary ribs but the primary ribs are all simple. These interspaces are crossed concentrically by wavy inosculating elevated lines like the fine lines on many crustacean carapaces. We should not venture to say that the shells are of Siluric type for the comparison made by Billings is only remote, but there is a certain similarity both in form and sculpture to the species described by Hall and Clarke as Orthis ? glypta from the Niagaran dolomites of Milwaukee [*see* Pal. N. Y. 1894. v. 8, pt 2, p. 359, pl. 84, fig. 8, 9] which has been compared with O. loveni Lindström from the Swedish Upper Siluric. One of the specimens appears to have cardinal spines near one extremity but this appearance is probably misleading as the shell may have here suffered an injury which has distorted growth.

Lower Devonic. Grande Grève, P. Q.

Hipparionyx minor nov.

The recognized distinction between the genera Hipparionyx and Orthothetes or Schuchertella lies chiefly in the orthoid form of the former and its very short hinge line. In respect to this character the specimens before us are pronounced. The ventral valves, small in comparison with those of H. proximus, have a short and low cardinal area, but in the dorsal valves the hinge line is apparently longer than correspondence with the opposite valve requires and these valves convey the impression of a straight and tolerably long line extending more than one half the width of the shell. On examination of the inner surface of this valve it is seen that this area is really short and confined to the apical part of the valve while the extended extremities are a thin expansion of the lateral parts of the valve which make a rather sharp turn at the cardinal angles. There is other divergence in the shell away from the type of Hipparionyx and toward that of Orthothetes as represented by such shells as Streptorhynchus umbraculum Schlotheim and its variant expressions.

In further detail, the ventral valve is subcircular or transverse with strongly defined and thickened adductor and divaricator scars. These are not however as large as in H. proximus. The beak is convex and slightly elevated but the rest of the valve is depressed or flat with a tendency to turn up about the margin and with indications of a broad and low median fold. The striae are



Hipparionyx minor

sharply elevated, increase very rapidly by implantation and on the cardinal slopes curve forward, out and back, in very characteristic manner. Very fine concentric lines are visible in the intervals between the striae. The dorsal valve is highly convex; the beak is not prominent, the convexity is generally uniform with slightly depressed cardinal slopes and sometimes a trace of a median groove. On the interior is a strong bifid cardinal process and a short median septum.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Orthothetes (Schuchertella) woolworthanus Hall mut. **gaspensis** nov.

See Strophomena woolworthana Hall. Pal. N. Y. 1859. 3: p. 192, pl. 17, fig. 1, 2; and

Orthothetes woolworthanus Hall & Clarke. Pal. N. Y. 1892. v. 8, pt 1, pl. 11, fig. 25-29, 31

It is not easy to discriminate species differentials in members of the genus Schuchertella (Orthothetes). In the forms before us we are presented with a shell which approaches in general aspect

O. woolworthanus of the Helderbergian (New Scotland) shaly limestone; it has the long and straight hinge, subsemicircular rarely subelliptical outline, sometimes elongated and in the character of the surface there is comparatively little difference. We observe, however, that in O. woolworthanus the ventral beak is rarely greatly elevated and distorted while this distortion is present in mut. gaspensis, giving the valve at times the aspect of O. deformis Hall (New Scotland beds). The shell substance is much the thicker in the mutation and the pallial surface is vascular. In the dorsal valve the muscle scar of the mutation is larger, sharply subdivided and the pallial surface strongly marked with impressions of mantle vessels, the trunks of which are median, departing forward from the front end of the muscle area. In O. woolworthanus the shell is so thin as to seldom show these scars. In both valves the plications are sharply defined about the periphery. On the exterior the mutation shows a rather regular inequality in the striae which in total are probably less in number. The differences are sufficient to indicate a modification of the earliest type expressed in S. woolworthanus.

The shell attains considerable size, fully that of large examples of O. woolworthanus.

Lower Devonic. Grande Grève and Shiphead, P. Q.

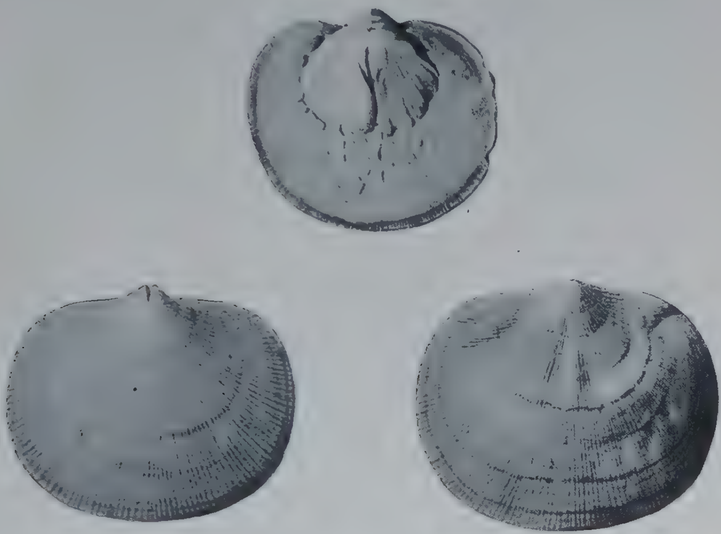
Rhipidomella logani nov.

Prob. Orthis oblata Logan (Billings) Geol. Can. 1863. p. 393
Orthis livia Billings (in part). Palaeoz. Foss. 1874. v. 2, pt 1, p. 32

Lens-shaped, subcircular shells, subequally convex in the posterior region, the ventral valve depressed anteriorly while the dorsal maintains its convexity. The slope of the surface of the dorsal valve is even in all directions and much more abrupt than in the ventral valve, the former is hence considerably the deeper valve. Little value can be laid upon the characters of the external markings which are in all these species fine, subequal, rounded and sharply elevated lines.

In the ventral valve the cardinal area is high and rather narrow, the delthyrium broad and the teeth well defined but not conspicuously elevated. The adductor scar is broad and flabelliform, extending one half the length of the shell and inclosing narrow and elongate oval diductors. The pallial region is well marked by pallial ridges which inosculate freely.

In the dorsal valve the cardinal area is narrow and not long enough to materially modify the almost circular outline of the valve. The crural processes are conspicuous and divergent and the car-



Rhipidomella logani

dinal process rather diminutive, curved forward, trifid at its end which does not project beyond the hinge.

In size, a width of 34 mm and a length of 29 mm is an average maximum and the limit of variation in size is not far from this.

Lower Devonic. Grande Grève, P. Q.

Rhipidomella lehuquetiana nov.

Shell small lenticular or subplanoconvex. General outline subcircular, a little wider than long. Ventral valve depressed, beak generally obscured or resorbed, umbo depressed; a broad and low sinus begins in the umbonal region, widens outward and becomes deep on the anterior margin making a strong sinuosity or tongue extending upward into the other valve. The surface at the sides of the sinus is broad and flat except about the margins where it is more abrupt.

Surface radii fine, rounded, numerous and subequal and cardinal area moderately high and curved downward at the sides. On the

interior the delthyrium is relatively broad and has encroached upon the beak, the pedicle cavity is deep, the teeth stout and thick. The adductor scars are very long, flabellate and extend almost to the anterior margin. They are bounded at the sides by the thickened extension from the teeth but in front they are not deeply impressed. They are divided by a median septum which almost reaches the margin. The diductor scar is elongate oval and posterior.

The dorsal valve is more regularly convex though flattened medially with angular slope in all directions. It is sinused on the anterior margin. The beak is blunt and the margins slope away from it at a low angle. On the interior the socket walls are stout

Rhipidomella lehuquetiana

and high, the sockets moderately deep and the cardinal process rather feebly developed, being fused with the adjoining walls and not projected beyond the hinge line; it is not divided. The muscular scars are posterior in a single or double subcircular pair separated longitudinally by a broad low and short ridge.

Dimensions. These shells measure in full growth about 15 mm in width by 12 mm in length.

This peculiar little shell which is quite abundant, bears the characters of senility as expressed in its thickened shell and shell processes and the usual resorption of the beak by the delthyrium. It has the general characters of Rhipidomella modified to the expression presented by Orthis dubia of the St Louis limestone [*see* Pal. N. Y. v. 8, pt 1, pl. 6A, fig. 18–22] which is a gerontic form with such outline.

Lower Devonic. Lehuquet's beach, Grande Grève, P. Q.

Rhipidomella hybridoides nov.

But for the extravagant size this shell attains at full growth it would be quite impracticable to distinguish it from American forms

of Sowerby's well known Upper Siluric Orthis hybrida. In its immature stages it is essentially that shell; at full growth

Rhipidomella hybridoides

its characters have changed by progression and indicate thereby a Postsiluric age.

Lower Devonic. Dalhousie, N. B.

Rhipidomella numus nov.

A shell directly comparable to R. (Orthis) oblata Hall of the Helderberg fauna, agreeing therewith in form and contour of valves though perhaps never attaining the size of that species. It differs therefrom: (1) in the slightly greater length of hinge, but principally (2) in the very much coarser and sparser plication of the surface. In R. oblata the radial striae are fine and crowded; in a typical example I find about 70 at a distance of 10

Rhipidomella numus

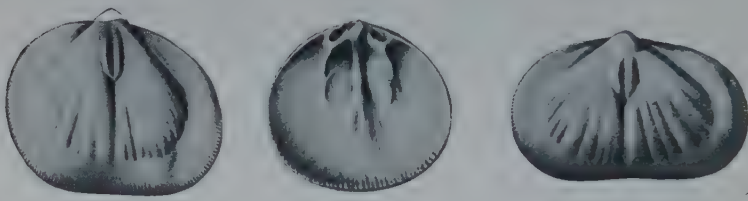
mm from the beak and at the anterior margin in a shell 32 mm long, 190. In the largest example of R. numus, 24 mm long, there are 40 at 10 mm from the beak, 106 at the margin. Thus there are practically two striae in R. oblata to every one in R. numus; those of the latter angular, multiplying rapidly. When compared with the rarer Helderberg species R. eminens, its plication is still much coarser, its hinge not so long and it lacks the elevated ventral beak of that shell.

The species is quite abundant.

Lower Devonic. Dalhousie, N. B.

Rhipidomella musculosa Hall var. **solaris** nov.

These are all small shells with the enormous adductor scar in a state of high development. The shells are somewhat less circular,



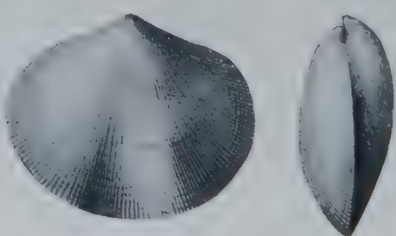
Rhipidomella musculosa var. solaris

more transverse than in the New York and Grande Grève Oriskany specimens of R. musculosa, but their specific identity is not greatly veiled.

Lower Devonic. Moosehead lake, Baker Brook point; Brassua lake, east side; Moose river at Stony brook, Me.

Schizophoria? amii nov.

Shell of medium size, transversely subelliptical in outline. Ventral valve with slightly prominent beak which is not depressed but from the umbonal region departs a low median sinus which widens posteriorly and covers one third the width of the valve at the anterior margin. The dorsal valve is the more convex specially



Schizophoria ? amii

in the median region which is elevated into a broad ridge corresponding to the concavity of the ventral. From this central ridge the sides slope somewhat abruptly and with a slight depression postlaterally. The surface is marked by fine angular radii very like those of Dalmanella lucia Billings (sp.) and are rapidly increased by implantation. Sometimes these striae are seen to end abruptly in elongate punctae as in some species of Rhipidomella (R. penel-

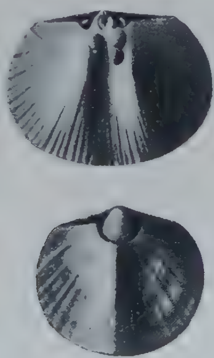
o p e Hall, Hamilton). The surface is crossed by fine and obscure concentric lines. On the interior the ventral valve bears flabellate muscle scars but it is not known whether the scars of the dorsal valve conform to those of Schizophoria. Specimens of this species are easily confounded with those of D a l. l u c i a but the contour of the two is exactly reversed.

Dimensions. A normal specimen measures 18 mm in length and 20 mm in width.

Lower Devonic. Grande Grève, P. Q.

Orthostrophia canadensis nov.

Valves subcircular with a straight hinge; in contour the ventral valve is the shallower but bears a high median ridge, while the deeper dorsal valve carries a broad and low median sinus. Inside, the ventral valve has the muscular area concentrated pos-



O r t h o s t r o p h i a c a n a d e n s i s

teriorly into a single scar not more extensive than the single pedicle scar in more typical orthids; the dorsal valve has a thin erect cardinal process and four distinct adductor scars.

The surface is marked by radial striae of unequal size.

Lower Devonic. St Alban beds. The Grande Cavée, and Cape Rosier Cove. This species is also known to occur in the Square Lake limestone of Northern Maine.

Dalmanella penouili nov.

This is a small circular shell without median depression or elevation but with an elevated ventral valve and high cardinal area, simulating in this regard a Schuchertella but without the deltidium

and having a short hinge line. The species is of the type of the Orthis lepidus Hall of the Hamilton shale fauna but is of larger size than that little species is known to attain. The surface

Dalmanella penouili

of the valves is finely striate, the elevated radial lines differing in size, a few being considerably larger than the rest.

Dimensions. The average among several examples has a width of 8 mm and length of 7 mm.

Middle Devonic. Gaspé Basin, P. Q.

Dalmanella drevermanni nov.

Cf. Orthis tectiformis Walther. Neues. Jahrb. für Min. Beil. bnd 17, 1903. p. 164, pl. 3, fig. 4 a-c

Orthis circularis Sow. mut. postuma Frech. Lethaea Paleoz. 1897. v. 2, pl. 24 b, fig. 8. *nom. nud*

Orthis circularis Sow. D'Archiac & deVerneuil. Trans. Geol. Soc. Lond. 1842. v. 6, pl. 38, fig. 12 (*non auctorum*)

Orthis subcarinata Hall. Pal. N. Y. 3: 169, pl. 12, fig. 7-21

This shell, the only one of its type in the fauna, is essentially a diminutive expression of Orthis subcarinata Hall of

Dalmanella drevermanni

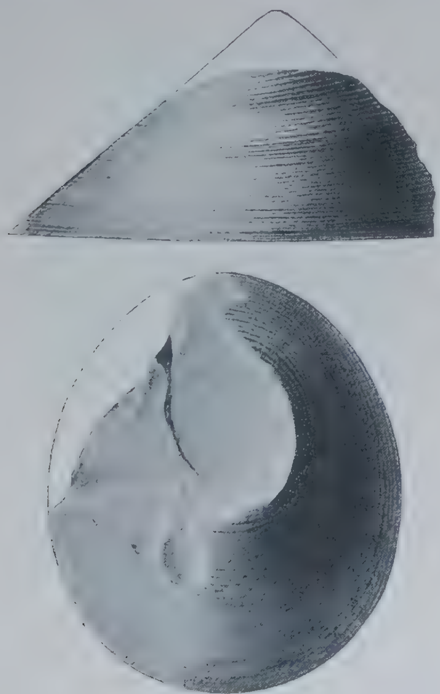
the New Scotland beds. It has however affiliations with other species, as cited above but the conditions of its occurrence oblige us to regard the form as wholly mature; though with reference to others its expression is immature. The exteriors of our shells indicate fine and somewhat unequal striation, with rapid multipli-

cation of the sharp riblets, an almost flat dorsal valve with low broad median depression and a medially elevated ventral valve with broad not acute keel. It is closely similar to Orthis tectiformis Walther, as cited, from the upper Coblentzian of the Haiger.

Lower Devonic. Edmunds Hill, Chapman Plantation, Me.

Orbiculoidea montis nov.

Shell very large, brachial valve highly elevated, suberect, much longer on the posterior than on the anterior slope. Posterior curvature concave beneath the arched beak; in front of the beak the surface is convex, the shell being uniformly expanded in the



Orbiculoidea montis

pallial region. Marginal outline subcircular. Surface bearing fine distant elevated concentric striae which may undulate and inosculate. These are crossed by very fine radial lines which probably do not pertain to the epidermal layer.

The pedicle valve is concave exteriorly though the beak is elevated and the pedicle slit does not extend to the margin.

Dimensions. One brachial valve, virtually uncompressed, has a diameter of 57 mm and its original hight was about 35 mm. Another which has undergone compression apparently had a diameter of about 65 mm. A pedicle valve has a diameter of 45 mm.

Lower Devonic. Grande Grève and Percé rock, P. Q.

Lingula elliptica nov.

Shell of moderately large size, outline elongate and regularly elliptical, there being for the dorsal valve very little difference in the curvature of the umbonal and distal extremities, the latter being very slightly transverse, the former quite regularly curved. Sides direct, for a very short distance only partaking of the curvature of

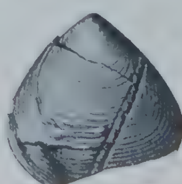
Lingula elliptica

the rest of the outline. Surface low and evenly curved, margin bordered all the way round by a narrow flattened area; exterior marked by concentric lines of the usual style. On the interior of the dorsal valve is a long and low median ridge or septum, but in the ventral valve there is no such feature. Length 19 mm, width 10 mm.

Lower Devonic. Grande Grève and Percé rock, P. Q.

Glossina acer nov.

Shell of relatively large size, subtriangular, with acute and prominent beak from which the margins diverge rapidly for more than



Glossina acer

two thirds the length of the shell, the distance across the pallial surface being four fifths the length of the shell. Anterior margin broad and nearly transverse. Surface covered by sharply elevated

and distant concentric lines which are mostly continuous though somewhat undulated but these frequently inosculate and become separated by narrower intervals toward the anterior margin. Length 17 mm, greatest diameter 13 mm.

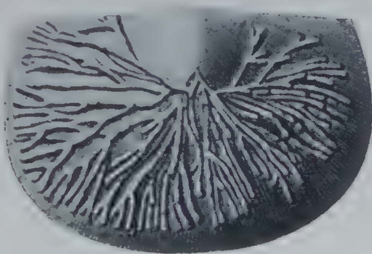
This shell is like L. perlata Hall and L. spatiosa Hall of the Helderbergian as the outline of those species has been represented but in this respect conjoined with the peculiar character of its surface markings, I am unfamiliar with any other species like it.

Lower Devonic. Grande Grève, P. Q.

BRYOZOANS

Hederella blainvillii sp. nov.

This very interesting bryozoan incrusts the shells of Leptostrophia blainvillii Billings and, so far as our observation has extended, seems to attach itself always to the ventral or upper valve at an early stage in the life of the brachiopod and grow out-



Hederella blainvillii

ward from the parent cell in all directions, keeping the apertures of the cells at or just a little distance above the margins of the shell. This habit evinces a true commensal condition not often shown in other cases of attached bryozoa; the water currents set up by the ciliated mantle of the brachiopod have helped to feed the members of the bryozoan colony, most of which stand in an attitude of readiness for this service. This species occurs with extraordinary frequency on these brachiopod shells and seems to grow on no other save for an occasional simply branched stock on an upper valve of Chonetes hudsonicus. Hederella ramea which I have described from the Oriskany of Becraft mountain, N. Y. elects attachment to Leptostrophia oriskania, always keeping its apertures toward the opening of the shell valves. From

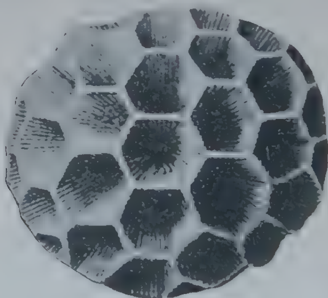
that species H. blainvillii differs in its much more rapidly branching zoarium and consequent shorter cells, producing a fuller and denser stock.

Middle Devonic. Gaspé Basin, P. Q.

CORALS

Pleurodictyum lenticulare Hall var. **laurentinum** nov.

Pleurodictyum lenticulare is a species of the Helderbergian (New Scotland) fauna characterized by its very large and few cells, the walls of which are strongly marked by nodose and broken septa. A central cell, hexagonal in form, is bounded by six others and it often happens that the development of this spe-



Pleurodictyum lenticulare var. laurentinum

cies does not pass this primitive expression. The form before us has the same form and size of cells which are marked by radial nodose and denticulated septa, these being most prominent and most irregular at the base. The lenticular corallum however grows to larger size, showing three cycles of cells about that which may be taken as central. In the measurements of the cells the New York and the Gaspé forms are alike.

Lower Devonic. Grande Grève and Percé rock, P. Q.

GRAPTOLITES

Chaunograptus gracilis nov.

A shell of Leptostrophia magnifica Hall has affixed to it an irregularly branching black conchiolinous repent fossil which in structure and substance seems to be congeneric with the peculiar organism described and figured by Hall as Dendrograptus (Chaunograptus) novellus from the Waldron (Niagaran) fauna [Geol. Sur. Ind. 11th Rep't. 1881. p. 225, pl. 1, fig. 1, 2; before in Alb. Inst. Trans. 1879, v. 10, abstract, p. 2]. A com-

parison with the two types of this species in the State Museum, shows that the Gaspé and Waldron forms are specifically different, the Gaspé form being coarser and the apparent cells larger. Since

Chaunograptus gracilis

no other form of this still problematic group of supposed repent graptolites is known, the Gaspé form is apparently new.

Its characters are: Conchiolinous, delicate, frequently and irregularly branching fronds, which are closely attached to foreign bodies and consist of curved, commalike bottle-shaped cells or branch segments, which are 1.4 mm long and .3 mm wide in their distal part and bud in such a fashion from the preceding that the branches become slightly zigzag-shaped.

Lower Devonic. Grande Grève, P. Q.

AN INTERESTING STYLE OF SAND-FILLED VEIN

BY

JOHN M. CLARKE

The margins of Port Daniel bay in eastern Quebec are fringed by vertical strata of Upper Siluric limestones rising in places to hights of several hundred feet. Over the eroded edges of these limestones are patchy deposits of the Bonaventure (Devono-Carbonic) sandstones and conglomerates, remnants of a sediment which has extensively sheeted this region.

At the east end of the bay, making the headland of Cap de l'Enfer, the limestones are of red and yellowish hues and are frequently seamed with vertical veins of inconsiderable size, these being parallel to, not transecting the dip. Many of these veins of quite irregular form resulting from an apparent deformation by solution and shearing of the original crack, have been but partially lined with deposition of calcite. The expanded portions of the fissures may be left wide open and empty but more often are filled by a regularly obliquely laminated deposit of dark red, compacted and cemented sand. An excellent illustration of these is shown here, the vein occurring in a yellowish limestone, the top being the eroded edge of the vertical stratum and the vein continuing down till it disappears in the water of the bay. The walls of this fissure are coated with a thin deposit of calcite uniformly laid on all surfaces, but nowhere meeting, while the cavities of the expanded portions of the fissure are filled with layers of red sand in curves concentric to the form which would result from deposition by gravity. It is entirely evident that this deposit of sand has infiltrated from the upper open mouth of the fissure, has sought and filled the lowest cavities first and it will be noticed has also filled the passage connecting the two lower cavities while the upper cavity and the passage leading to it still remain open ready to receive additional deposits. This red sand is very sharply laminated and well compacted. Its color and composition leave little doubt that it has been derived from the Bonaventure conglomerates during the period of their erosion and that this erosion was accomplished before the fissure was wholly filled. There is no longer

any possibility of completing this process for now the nearest outcrop of the red conglomerates and sandstones is some rods away and below the level of these fissures.

This purely mechanical filling of a fissure is in its process unlike many of the recorded examples of sand veins and dikes where the filling has resulted from normal deposition of sand on an eroded and fissured surface. The writer has described the case of the Oriskany sand penetrating to fissures in the underlying Siluric rocks at Buffalo, N. Y. Many parallel and far more striking cases of similar character are known and have been described by various writers, Diller, Cross, Geikie, Pavlow, but the case here described differs from these in the evident filling of the fissure, not at the time of deposition of the overlying sandstone deposit, but at the time of its erosion, through the action of a small infiltering surface current. This conclusion is fairly established by the vacant upper cavities of the fissure indicating an entire removal of the supply of material before the filling of the cavity was complete.

THE EURYPTERUS SHALES OF THE SHAWANGUNK MOUNTAINS IN EASTERN NEW YORK

BY

JOHN M. CLARKE

In the recent efforts to correlate the stratigraphy of the Paleozoic rocks of eastern New York with the more lucid succession in the central and western portions of the State, the present viewpoint indicates some unsettling of long recognized values which have been ascribed to the formational units of the former.

In eastern New York we have to deal with paleogeographic conditions which were doubtless diverse from those further west in the old open Paleozoic gulf and until the recognition of the difference in these conditions no trustworthy correlation could be approximated.

Briefly summarized for our present purpose, these old physiographic differences are evinced first by the existence of an isolated tongue of late Siluric and early Devonic deposits beginning at Skunnemunk mountain in Orange county and running southwestward into New Jersey, the Skunnemunk basin as it has been termed by Ulrich and Schuchert. For this area which has been carefully studied by several geologists we must employ the term basin with reserve as it is an area of very steep dips, at the north separated from the more western band of the same formations by a broad area of the "Hudson River" (Lorraine, Utica and Trenton) shales, and at the south by the crystallines and intrusives of the protaxis. There are many excellent reasons to regard this area as the eastward branch of a broadened anticline whose decapitation has exposed both the Lower Siluric beds and the crystallines, and its actual present outcrops may eventually be shown to merge toward the north in the vicinity of Kingston with the parallel western band of contemporaneous deposits. This is a point requiring more refined investigation. The other factor in this divergence of physical conditions is the fairly demonstrated existence in the early Paleozoic of a rising barrier at the head of the Appalachian gulf, occupying the present site of the Helderberg mountain and forcing deposition at as early a period as the late

Siluric around the southern margin of this barrier, hence excluding these in large measure from the outcrops now exposed along the northern and eastern edges of the Helderberg escarpment.

The key to the recognition of these physiographic differences east and west was found first in the stratigraphic value of the formation in eastern New York termed by the early geologists the "Coralline limestone" and accepted by them and their successors as such eastern representative of the Upper Siluric Niagara or Lockport dolomitic limestone of western New York. We term this formation at the present time, or such part of it as was called by Hall, who described its fossils, Coralline limestone, the *Cobleskill dolomite.*

The very refined study of this formation made by C. A. Hartnagel and published in these reports has shown not only the continuity of this unit across the State from west (Buffalo) to east, interrupted from Schoharie to Rondout or along the north edge of the Helderberg, but also demonstrated its position at the top of the Salina formation, hence of far later age than the Niagaran. With this well determined fact in hand this formation, heretofore used as a bench mark for the assignment of the formations in eastern New York above and below it, again serves a similar purpose and necessarily involves important modifications in correlation. Following the clues herein suggested, Mr Hartnagel has recently given attention to the stratigraphic value of the Shawangunk grit which constitutes as a heavy sheet of arenaceous deposits all except the basal parts of the Shawangunk mountains in Ulster county and extends south through western Orange county into New Jersey.

This extensive series of arenaceous deposits has been, from the earliest classification of the formations, uniformly interpreted as of the age of the Oneida conglomerate of central New York, but Hartnagel's researches indicate with probability that in its typical localities this Oneida conglomerate is a local phase of Medina sedimentation and lies within the recognized upper limits of that formation. In the Skunnemunk region the Shawangunk grit is separated from the Cobleskill limestone by a series of formations of upper Salina age which in their extension from Ulster county to New Jersey vary considerably in thickness, lithologic character and fossil contents.

The details of these later correlations are published in Mr Hartnagel's article appearing in another part of this bulletin. The

prime inference that concerns us in this place is that the Shawangunk grit so far from being an eastern representative of the Oneida conglomerate of early Upper Siluric age is actually the arenaceous representative of the Salina period in eastern New York. Hartnagel's investigation of this problem is based wholly on stratigraphic evidence; the paleontology of the formations involved was not taken into account and indeed there was not at the time any paleontologic evidence to be considered so far as the Shawangunk grit is concerned for no fossil had ever been seen in it.

We here present a noteworthy corroboration from novel and extremely interesting paleontologic evidence of this correlation originally made upon purely stratigraphic data.

In typical sections of the Salina series of formations in western New York, the peculiar arid conditions of this epoch are accompanied and indicated by the appearance of a profuse and remarkable crustacean fauna presented by the Pittsford shales and described by the writer in New York State Paleontologist Report, 1900, pages 83 and 92, and C. J. Sarle in New York State Paleontologist Report, 1902, page 1080.

Although it has been possible to exploit these shales in only one locality, in and along the Erie canal near Pittsford, Monroe co., the fauna which has been described covers the merostomes Eurypterus, Pterygotus, the new genus Hughmilleria, Pseudoniscus and the phyllocarids Emmelezoe and Ceratiocaris.

The black shale with this fauna graduates by alternation into the thin waterlimes above and it is not until the lapse of the entire sedimentation of the Salina, which at its climax involved extreme salt pan conditions, that the merostome fauna comes back in the final stage of the period with the breaking down of barriers and the freshening of the waters. This later phase is the period of the Bertie waterlime with a rich and widely known fauna of Eurypterus, Pterygotus, Dolichopterus, Eusarcus, Pseudoniscus, Ceratiocaris etc.

During the past season, my assistant Dr Ruedemann, having occasion to visit Otisville, in western Orange county, to examine some graptolite-bearing layers of the "Hudson River" shale to which my attention had been courteously directed by Dr H. B. Kümmel, visited a quarry in the Shawangunk grit alongside the Erie Railroad at that place and there observed a black shale layer

in the grit, from which he obtained a few very evident segments of Eurypteruslike merostomes.

The discovery of such fossils in eastern New York, long looked for but never before found, and their evident importance in the correlation of the sediments, rendered it desirable that these beds should be extensively exploited.

This work of collecting has been carried out successfully by Mr H. C. Wardell and the material on which the following account of the stratigraphy of the fossils is based is quite extensive.

The present line of the Erie Railroad from Otisville west for a distance of a mile or two passes over the steep grade of the Shawangunk mountain. Extensive operations are now under way to reduce this grade by a tunnel directly through the mountain. The present railroad cut at the summit of the hill transects inclined layers of the Shawangunk grit and above this cut at the east lies the long quarry face from which the crustacean remains were first obtained. This rock face has been torn into extensively in the removal of rock which is crushed and used for ballast.

The stratigraphy along this section is as follows: About ¼ mile west of Otisville along the railroad are "Hudson River" shales standing at an inclination of about 45° w. Westward the eroded edges of these shales are abruptly overlain by the conglomerate basal layers of the Shawangunk grit series, the Green Pond conglomerate of Darton and the New Jersey geologists, which in the expansion of the formation in the Kittatinny mountain attains a much greater thickness than here. In the railroad cut these conglomerate layers attain a thickness of about 50 feet but pass gradually into the finer typical grit above. The thickness that may be ascribed to the grit here is 450 feet and it again passes upward into looser sandstones.

One half mile south of this section along the Erie Railroad the beds referable to the Shawangunk series attain a thickness of approximately 550 feet. From the base of the series at the contact with the Lorraine shales through a section 350 feet are innumerable thin layers of black shale. Above this the thin shale layers become gray and more argillaceous but continue to carry the merostome fauna with the addition of some singular phyllocarids whose structure has not yet been completely made out.

Mr Wardell has measured this section in detail and the full statement of it is very interesting as showing the remarkable continuation of these alternations of black shale bands through the arenaceous deposits.

Plate A

Unconformity between basal conglomerate layers of Shawangunk grit and the "Hudson River shale." The latter contains fossils of Utica age. Erie Railroad cut just west of Otisville

Section of the Shawangunk series in ascending order

Erie Railroad cut ⅓ mile west of Otisville

129 ft of "Hudson River" shale with interbedded thin layers of sandstone

Unconformity

SHAWANGUNK SERIES

12′ conglomerate
2″ shale
8′ conglomerate
2″ shale
1′ conglomerate
2″ shale
16′ 8″ conglomerate
2″ shale
6′ 10″ grit
6″ shale
2′ 10″ grit
6″ shale, thinning out rapidly
13′ 5″ grit
2″ shale
5′ grit
4″ shale
7′ grit
1′ shale becoming thicker at top of cut
41′ grit
50′ (estimated) of grit not exposed between top of railroad cut section and base of quarry section

Erie Railroad quarry ⅓ mile west of Otisville

101′ grit
5″ shale
3′ 6″ grit
2″ shale
2′ grit
2″ shale
7′ 6″ grit
2″ shale
12′ grit
8″ shale
3′ grit
10″ shale
17′ 2″ grit

4″ *shale*
6″ grit
1″ *shale*
4″ grit
2″ *shale*
3′ 8″ grit
2″ *shale*
7′ grit
2″ *shale*
11′ grit
1″ *shale*

Productive band. From a vertical section of 23′ 6″ beginning 198′ 7″ above contact of Shawangunk grit and "Hudson River" shale

2′ 2″ grit
2″ *shale*
1′ 2″ grit
2″ *shale*
8′ grit
5″ *shale*
9′ grit
2″ *shale*
4′ grit
10″ *shale*
3′ grit
1″ *shale*
8′ grit
1′ *shale*
21′ grit
4″ *shale*
8′ grit
2″ *shale*
1′ 9″ grit
2″ *shale*
1′ 6″ grit
3″ *shale*
5′ grit
2″ *shale*
6′ grit
4″ *shale*
10′ grit
2″ *shale*

Very productive band in section 16′ 8″ beginning at 298′ 5″ above contact

22′ grit
2″ *shale*
6′ grit
3″ *shale*
1′ 6″ grit
2″ *shale*

Productive band; section of 1′ 9″, 343′ 3″ above contact

10′ grit
3″ *shale*
7′ grit
4″ *shale*
60′ grit (estimated) with occasional very thin layers of shale. As these 60′ have not been quarried shale layers have been weathered away at exposures.

Plate B

Quarry in Shawangunk grit, Shawangunk mountain, ½ mile west of Otisville. The black shales are intercalated at frequent intervals and in discontinuous patches among the grit layers.

It is these shale bands indicated by italics that contain the crustacean remains. No one of them exceeds a few inches in thickness and while it is not to be said that every layer has afforded fossils, yet it is to be expected that each may. The most productive layers have thus far proved to occur in groups as indicated on the section. These shale layers are not often continuous along the bedding either for the entire strike or dip of the section but they thin and pinch out, reappear and continue for a short distance to again vanish; in other words they occur in a multitude of originally horizontal patches over the surfaces of the sand layers. This section therefore is but a statement of variation in sediment along a given horizontal; above or below the succession would probably vary in some measure. The shales carry no other fossils than the crustaceans or at least none have yet been found and the sands have afforded nothing in the way of fossils except a few bodies resembling in some respects Arthrophycus harlani Hall (A. alleganiensis Harlan) which the weight of evidence brought forward by the recent investigations of these problematical bodies by C. J. Sarle indicates to be a worm burrow.

The preservation of the crustacean remains in the black shale is peculiar and in some respects unusually favorable for the study of the smaller organisms of the fauna. The parts are altered to a shining coaly film usually incrusted by a tenuous layer of pyrite which when moistened brings out details of structure not otherwise to be ascertained. Indications are at hand of an extensive and commanding crustacean fauna. Great masses of mangled and dismembered parts indicate how extraordinarily abundant these Eurypterids have been, but entire individuals are great rarities. The carapaces, segments and limbs afforded smooth flat surfaces which have invited the process of shearing and this has usually glazed the bodies and often destroyed the half of their surfaces. Young forms, probably because of their size and compactness, seem to have more often escaped dismemberment while larger ones are represented by only an occasional fragment of striking size. Heads, especially of young animals, are common but even these broad shields in larger animals have been too thin to resist the shearing pressure upon them. The range in size of the animals here present is worthy of especial note. We have entire animals ranging from 2.5 mm to 5 mm in length, by far the smallest and youngest Eurypterids yet recorded and exceedingly interesting for the ontogenetic evidence they afford; and there are body segments which indicate creatures of great size—that is a probable length of

several feet, proportions hardly exceeded in Beecher's well known restoration of the Catskill Stylonurus excelsior and only surpassed by a great, but little known Pterygotus from the Bertie waterlimes in Herkimer county.

In the descriptive account of these fossils, we have indicated an affinity with the fauna of the Pittsford shales of western New York which is emphasized by the character of the deposit in which they are involved. It is entirely safe to say that the fauna carries sufficient evidence of an historic stage earlier than the predominant Eurypterus fauna of the Bertie or final stage of the Salina.

The evidence to be drawn from the Arthrophycuslike fossil from this grit as indication of approximation in age to the Medina formation of western New York is entirely negligible as its significance is not material as an index fossil.

The presence of this crustacean fauna in the Shawangunk deposits thus may be taken as conclusive of the Salina age of the entire series of conglomerates and sandstones. This inference, if substantially grounded, brings us to an enlarged and modified conception of the coastal physiography during the phases of the Salina period.

The Shawangunk mountains and their extension into the Kittatinny range of New Jersey lie on the eastern boundary of the Appalachian gulf and their sediments while depositing were embraced in it.

Referring again to the normal Salina succession in western New York, we recognize the introductory, culminant and decadent stages of the Salina sea representing respectively the gradual shoaling of the shore waters with the formation of bars, brackish lagoons and salt pools, the complete abscission of the waters within the barriers forming a salt lake of saturated brine in which no organism has left a trace, and finally the breaking down of the barriers and restoration of normal marine conditions.

No such consecutive conditions present themselves at the eastern boundary of the gulf during this period. Here rapid deposition was in continuous progress with no further evidence of seclusion from the main gulf waters than is afforded by the presence of these black shale layers and their fauna. We have had occasion elsewhere in discussing the bathymetric value of bituminous shales, to bring forward the very strong evidence for their formation at great depths, arguments abundantly supported by the writings of others, but it is probably needless to state that certain dark shales not necessarily bituminous carry accessory evidence of deposition

in shallow water. Our present knowledge of the habits of the merostome crustaceans derived both from the living and fossil forms, indicates the shallow water or barachois origin of all sediments in which these remains abound. In the Shawangunk section we have a fauna constantly repeating itself through a thickness of 650 feet which elsewhere appears only and briefly at the base of the Salina series.

While it may seem hazardous to infer that this section represents only the early part of the Salina stage, yet the section of these rocks afforded by the Nearpass quarry at Port Jervis shows that above the Shawangunk grit are the red Longwood shale, Poxino Island shale, Bossardville limestone and the Decker Ferry limestone. All these are below the layer now correlated with the Cobleskill horizon of central and western New York. At Poxino island, Dr Kümmel estimates the thickness of the red shale at 2305 feet. We have then in southeastern New York and northern New Jersey a very great thickness of deposits which now seem to be the equivalent of the Salina shales and dolomites of central and western New York and though in the latter region it has been found practicable to subdivide the Salina deposits into a series of minor stratigraphic units, the total thickness of them all is very much less than one half, probably considerably less than one third of the thickness of the deposits which we may ascribe to the same stratigraphic interval in the region under discussion.

The continuity of this crustacean fauna indicates uninterrupted communication through the secluded waters of this period. Were it not for the presence of the fauna at the east one might entertain the conception of a torrential origin for the heavy mantle of Shawangunk grit. This might be in entire harmony with the prevalent arid condition of the time, but the innumerable repetitions of this fauna preclude this idea. This arenaceous deposit, we have noted, belongs to a portion of the gulf set off from that further west by the protrusion of the Helderberg shoal or peninsula, an eastern bay receiving a rapid terrestrial drainage with resultant deltiform deposition of low gradient, from an elevated but distant source. The intrusion of these terrestrial waters at the east prevented highly saline conditions.

Description of the fauna

In attempting to portray the character of this interesting association of merostomes I am obliged to recur to the statements already made in regard to the preservation of the bodies. Cir-

cumstances have permitted the retention of the smaller parts, chiefly very young entire individuals or head shields of immature forms, but have almost wholly destroyed larger bodies or left merely patches and fragments of them. Thus this attempt encounters two serious obstacles which may constitute two distinct sources of error: (1) the effort to ascribe to very imperfectly known mature animals a variant series of young stages; (2) the recognition of the character of mature adults and representatives of large genera from the parts which have by accident escaped total destruction from shearing and compression. Added to both of these difficulties is the consideration that the appendages of all forms have rarely been observed. A very determined effort has been made to overcome these defects by the acquisition of copious material. The fossils are not abundant. It has required the handling of a great many tons of rock to acquire the half ton or so of specimens from which the selection has been made for this descriptive account. The future will complete our knowledge of the fauna; for the immediate present we may content ourselves with the remarkable evidence it affords of the age of the Shawangunk grit and of ontogenetic variations hitherto unrecognized in this group of animals.

MEROSTOMATA

Order EURYPTERIDA

Family EURYPTERIDAE

Genus EURYPTERUS

The typical adult Eurypterus carries 12 tergites or dorsal segments and a telson. On the ventral side the number of segments or sternites is reduced by one by the fusion of the first two into the genital operculum. There have been few exceptions recorded to this numerical value of the segmentation and it is generally recognized as standing for the proper expression of complete segmentation in the entire family. It is interesting to note that the earliest well known Eurypterid, Strabops thacheri Beecher, described from a large entire specimen from the Cambric of Missouri, carries but 11 segments.[1] This would be a phylogenetic condition entirely compatible with the ontogenetic expressions presented by the material now before us, wherein we have very young phases of Eurypterus with 11 and an extremely early stage of Hughmilleria with apparently but 10 segments.

[1] Beecher, C. E. Discovery of Eurypterid Remains in the Cambrian of Missouri. Am. Jour. Sci. 1901. 12:364.

The addition of segments with growth may be regarded as a normal procedure in these Eurypterids as it is known to be in Limulus and the trilobites. Other ontogenetic variations will be referred to under the accounts to be given of the various species recognized.

Eurypterus maria nov.

Plate 1, figures 1–4; plate 2, figures 1–7; plate 3, figures 1–7

The general form of the largest observed individuals of this species [pl. 1, fig. 3; pl. 2, fig. 2] is elongate and slender with very little abdominal expansion and no lobation of the segments. In these ephebic conditions the head is somewhat elongate, regularly rounded in front and with subparallel lateral margins. The eyes are crescentic, subcentral, as far asunder as the inner margin of each is from the margin of the shield.

The ocellar lobe is well defined at an early stage. A specimen 63 mm long without the telson, apparently mature, has 11 segments, but a break across the body leaves room enough for a 12th. The width of the base of the head is 15 mm and this is but very slightly less than the greatest expansion of the abdomen. Little trace of surface sculpture is visible on any of the parts.

Immature phases. The smallest individual that can be referred to the species has an actual length of 5 mm [pl. 2, fig. 1] and possesses seven relatively broad segments tapering without expansion backwards. Although this specimen is not complete, at the extremity it has tapered so rapidly that there is little place for anything additional but the telson. Only suggestions of structural features are to be seen on the head. On plate 1, figure 1, is a more complete animal, 5.5 mm in length with 11 segments and the telson. Here again are only suggestions of structure on the head, but very noteworthy is the marked contraction of the postabdomen bringing out strongly the scorpioid abdomen which now seems indicative of a nepionic condition both in ontogeny and phylogeny. Probably certain well known large merostomes like Eurypterus scorpioides and species of Eusarcus in which this abdominal expansion is pronounced at maturity, are to be interpreted as arrested in respect to such development. In the chapter on the Merostomata in Zittel-Eastman's *Textbook of Paleontology* I introduced figures of immature examples of Eurypterus remipes [p. 676, fig. 1420, 1421], the smallest individuals of any Eurypterid known at that time, wherein this abdominal contraction and expansion is strongly pronounced and in the smaller of the two there is also a very marked paucity of abdominal segments. This abdominal con-

traction in E. maria is not long retained. Plate 1, figure 2 shows an entire specimen with a full supply of segments and with relatively broader abdomen than in the mature form but its outline gradually rounds to the more slender posterior segments. The length of this specimen is 8 mm. In the incomplete individual shown in figure 4 of the same plate all the essential features of maturity appear to have been assumed, even the eyes and ocelli having their normal development. This fragment represents an animal probably 10-11 mm in length.

The variability of the eyes in size and position in these young phases invites special attention. We have figured on plates 2 and 3 a considerable number of these head shields and it will be observed on consulting these figures and their accompanying natural size outlines that while there is no direct relation between the size of the head and the size and position of the eyes the instability of these features loses itself on the approach to adult size. Accompanying these changes there is an equally irregular variation in the outline of the head which from being short and almost semilunar gradually approximates the more elongate form of the ephebic type [pl. 2, fig. 2].

We may therefore summarize the ontogenetic changes derivable from the evidence which this species presents as follows: (1) Very early change from the scorpioid to the gently tapering abdomen; (2) gradual but irregular increase in segmentation; (3) gradual but irregular elongation of the head; (4) highly irregular variation in position of the eyes, but gradual travel from the margins inward to their normal locus.

Eurypterus myops nov.

Plate 6, figures 1–5, 6 (?)

This species is in many respects a diminutive expression of Eurypterus pittsfordensis Sarle, the head (all that is now known of it) being subquadrate, almost as much squared in front as behind, the eyes large, semicircular, subcentral and approximate and the ocellar mound developed in mature forms. The material is insufficient to establish any marked variations in growth, as the species is among the less common forms of the fauna. One example shown in figure 6, which is doubtfully referred to the species has the eyes large and almost marginal. There is a striking similarity between this species and the last of the Eurypterid race, the Eurypterus described by de Lima from the Permian of Bussaco, Portugal.

Eurypterus ? cicerops nov.

Plate 5, figure 10

This diminutive head shield is remarkable for the extraordinary development of the compound eye lobes which are anterior and very prominent and though the shield has a diameter of only 4.5 mm, the ocellar mound is fully developed. So unusual is the aspect of this specimen that it can not be assigned to any of the other species here noted, and though entirely immature, it is given a distinctive designation.

Eurypterus ? cestrotus nov.

Plate 3, figures 8–10

Of this species we have only enough to satisfactorily establish its difference from other forms—the two specimens here illustrated. Both show the peculiarly ornamented frontal border of the cephalon which carries a row of denticulations. One of these specimens conveys a satisfactory idea of the form of the body, and presents the ventral aspect but there is some uncertainty in regard to the number of segments and though evidences of four pairs of legs are present the structure of these is not apparent. The head shown in figure 10 indicates that the compound eyes are large and very far forward. It is entirely probable that when this species becomes better known it will have to be excluded from the genus Eurypterus.

Genus HUGHMILLERIA

This genus was established by C. J. Sarle[1] on specimens obtained from the Eurypterus-bearing Pittsford shales lying at the base of the Salina group in Monroe county, New York.

Hughmilleria has been represented heretofore only by the type species H. socialis, and its var. robusta. The critical structural difference between this genus and its close allies Eurypterus and Pterygotus is the existence of chelate preoral appendages, much larger than in Eurypterus (E. fischeri Eichwald) very much shorter and smaller than in Pterygotus, but with the marginal eyes of the latter genus. The form of the animal is slender and terete with no marked abdominal contraction while the head has an elongate rounded subtriangular outline which is quite characteristic. The species here assigned to the genus Hughmilleria has been so treated on the basis of its form and the shape and structure of the head; the chelate appendages have not been found and

[1] A new Eurypterid Fauna from the Base of the Salina of Western New York. N. Y. State Paleontol. Rep't 1902, 1903. p.1080.

in the absence of these there must be some reservation made, subject to future demonstration or correction.

Hughmilleria shawangunk nov.

Plate 4, figures 1-4; plate 5, figures 1-9

With the same form of head and outline of body as in H. socialis this species combines a diminutive size, the average being well shown in figures 1 and 3 of plate 4. The full equipment of abdominal segments (12 and telson) is possessed at this adult stage.

Exceedingly instructive but of the same tenor as evidence already given are the developmental stages. On plate 4, figure 2 is represented under great enlargement from a camera drawing an entire individual 2.5 mm in actual length, the smallest known of the fossil merostomes. This is in no sense a nauplius and we are entirely without evidence of any such stage in these crustaceans. It is however an emphatic expression of the differences between the nepionic condition and the adult, showing the short, broadly triangular head, the expanded abdomen which under the best illumination appears to carry but five segments and the abruptly contracted postabdomen with five narrow and deep segments. Thus again in this very early growth stage is the scorpioid outline sharply defined. On consulting the figures of various head shields of different sizes shown on plate 5, it will be seen that there is not much variation in the position of the eyes. In some instances the eyes are not discernible [fig. 5, 6] and it is quite possible that in these they may be still entirely submarginal.

Genus PTERYGOTUS

Pterygotus ? otisius nov.

Plate 6, figure 7

An elongate subquadrate head with eyes anterior, far apart and just within the margins; ocellar mound well back between the posterior horns of the eye crescents; surface quite smooth. The specimen figured and one other of similar character are all that is known of this species.

Genus STYLONURUS

Stylonurus ? sp.

Plate 6, figures 9 (?), 10 (?), 11, 12; plate 7, figures 1–5; plate 8, figures 9, 11 (?)

Everywhere through these dark shales are fragments of large crustaceans most of which are so distorted as to no longer show the outline of the parts though they exhibit distinctive surface

characters. Occasionally a large segment is recognizable, and the figures cited show such parts as are more or less definitely determinable. Thus we have the terminal joints of a long cylindrical appendage [pl. 7, fig. 1] which evidently represents the long fifth leg in Stylonurus. Figure 12, plate 6 and figure 9, plate 8 are also long, slender leg joints which probably pertain to small individuals of the same genus. Some of the abdominal segments are noteworthy for their lobation, a large one is shown in figure 11, plate 6 and smaller ones of the same type in figures 9 and 10 of the same plate. The largest of these has been so subjected to lateral compression by shearing that the left moiety has been distorted beyond recognition, while the same pressure has developed the lobar depression at the right into a distinct break or suture. Such lobed segments are rare in all Eurypterids but are especially noteworthy in a species which has been described by Fr. Schmidt as Stylonurus? simonsoni from the Upper Siluric of Rotziküll, Oesel.[1] The principal specimen on which this species is based consists of a part of the underside of the head with the opercular plates and 6 to 7 abdominal segments. In all these the dorsal furrows are sharply defined and divide the segments into a convex, broad median part and flat lateral portions which can not be regarded as having any relation to the so called "epimera" of Pterygotus. It is true that in typical expressions of Stylonurus such as S. logani Woodward, and S. excelsior Hall there is no evidence of such lobation of the abdomen and though Schmidt has found with these abdominal parts the long leg joints just as we have similar parts associated in the Shawangunk shale there is very excellent reason for the presumption that we are here dealing with creatures which when more fully known will prove to be generically distinct from Stylonurus. The great size attained by some of these bodies in the Shawangunk shale is notable, and in contrast with the rather diminutive series of forms we have been dealing with. Some of the creatures must have attained a length of 3 to 4 feet, but per contra, this would be a small size for Stylonurus, the large forms of which have been shown by Woodward and by Beecher to have reached a length of 7 to 8 feet.

Phyllocarida

Plate 6, figure 13; plate 8, figures 12, 13, also 14–21 (?)

Two very different species of Phyllocarids are indicated by the caudal parts as shown on plate 8, figures 12 and 13, one having

[1] Bul. de l'Acad. Imp. des Sciences de St Petersburg. 1903. 5 ser. 20:199.

a slender telson spine with longer, slender and apparently curved cercopods, the other with a heavy telson much longer than the cercopods which are short bladelike and longitudinally striated. These are both from the black shales of the grit and neither can be more exactly determined generically than by the term Ceratiocaris. In the gray shales above the grit have been found a number of fragments of bodies no one of which gives any clue to its exact outline save that they are sometimes rounded at one extremity and all are ornately engraved by longitudinal anastomosing lines or groups of continuous or broken lines as illustrated on plate 8, figures 14 to 21. I think there is no reasonable doubt that these are carapaces and parts of segments of Phyllocarids, but if so, of a type of structure heretofore unknown. Future investigations will, it is hoped, elucidate the nature of these peculiar bodies.

In the Pittsford shales there are Phyllocarids which I have described under the names Ceratiocaris precedens and Emmelezoe decora and it is usual to find these crustaceans associated with the merostomes in all the Upper Siluric occurrences of the latter.

EXPLANATION OF PLATES

PLATE I

Eurypterus maria nov.

Page 305

See plates 2 and 3

1 An entire individual 5.5 mm in length. This specimen presents 11 segments and telson, so far as it has been possible to determine them. On the left side the abdominal contraction is emphasized, in some measure perhaps by distortion. On the carapace the size and position of the eye spots as represented is somewhat presumptive in view of the character of the preservation.

2 Another individual entire except for a part of the telson and having an actual length of 8 mm. Here the postabdominal contraction is slight, the total number of segments 12, the eyes apparently almost marginal although this position is again uncertain, and traces of legs are seen.

3 An incomplete specimen 20 mm in actual length. This presents in part the ventral aspect of the animal, showing the position of the metastoma in place, one swimming foot and segments.

4 A specimen with an actual length of 8 mm, head and seven segments. The head shows fully developed subcentral eyes and central tubercle bearing the ocelli.

G. S. Barkentin, del.

PLATE 2

Eurypterus maria nov.

Page 305

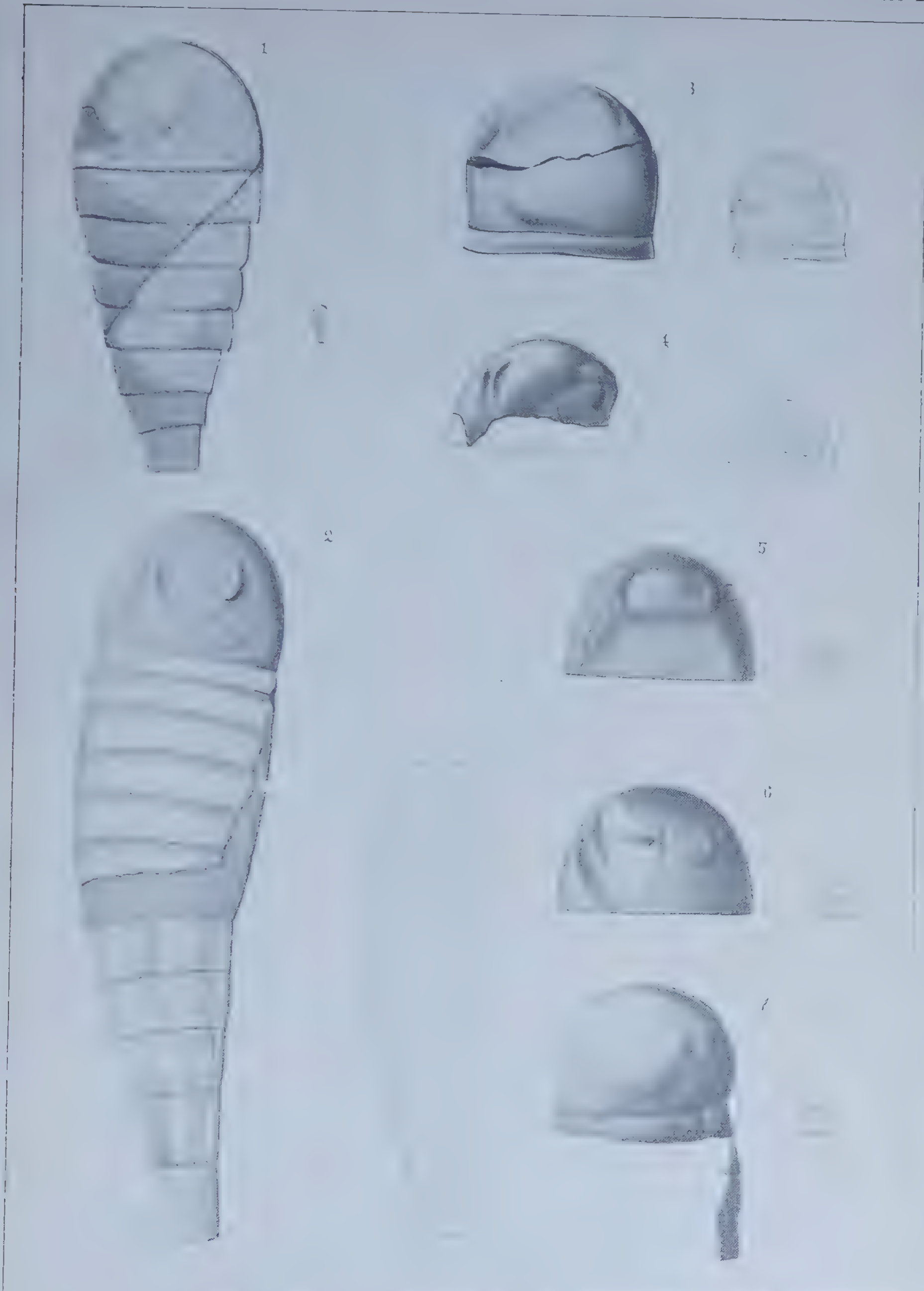
See plates 1 and 3

1 A specimen 5 mm in length, with head and seven segments.

2 This individual is the most nearly entire of any example of this species observed which approaches the features of maturity. It carries head and at least 11 segments and the slender form of the body at this stage is specially noteworthy. The actual length of the specimen is 63 mm.

3 A head with neck segment attached and with eyes very close to the antelateral margin. The natural size outline in this and the following figures is at the right.

4-7 Head shields of various immature phases with eyes well developed but still holding an anterior and intramarginal position.



G. S. Barkentin, del.

PLATE 3

Eurypterus maria nov.

Page 305

See plates 1 and 2

1-7 A series of the heads showing notable variation in the position and size of the eyes. All are immature phases and the variation of these features seems to have but little direct relation to the size of the animal. In figure 3, the eyes are apparently absent.

Eurypterus ? cestrotus nov.

Page 307

8 An individual, natural size, so crushed as to obscure the distinction of the cephalic parts but indicating the general form of the animal and its segmentation. In figure 9 is given an enlargement of the peculiar denticulate anterior cephalic margin.

10 A head with portions of segments of a young individual, showing the same denticulate margin. The eyes seem to be large and far forward and the whole expression of the head is such as to convey the belief that the animal pertains to a genus as yet undefined.

G. S. Barkentin, del.

PLATE 4

Hughmilleria shawangunk

Page 308

See plate 5

1 An average mature example with 12 segments and telson and one crawling leg. This specimen shows the approximation in form of body, shape of head and position of eyes to H. socialis.

2 The smallest entire individual yet observed and regarded as pertaining to this species. This specimen has an entire length of 2.5 mm, its head is short, broadly subtriangular and the eyes can not be located. Especially notable is the broad scorpioid abdomen emphasized by the contraction of the postabdomen. So far as it is possible to determine, the abdomen carries not more than five segments, the postabdomen the same number, more clearly defined.

3 A nearly entire individual with an actual length of 40 mm, retaining portions of the appendages. The number of segments is represented as 10 but it is not certain that some may not be lost by overlap.

4 A head and two segments; showing eyes and ocelli.

G. S. Barkentin, del.

PLATE 5

Hughmilleria shawangunk nov.

Page 308

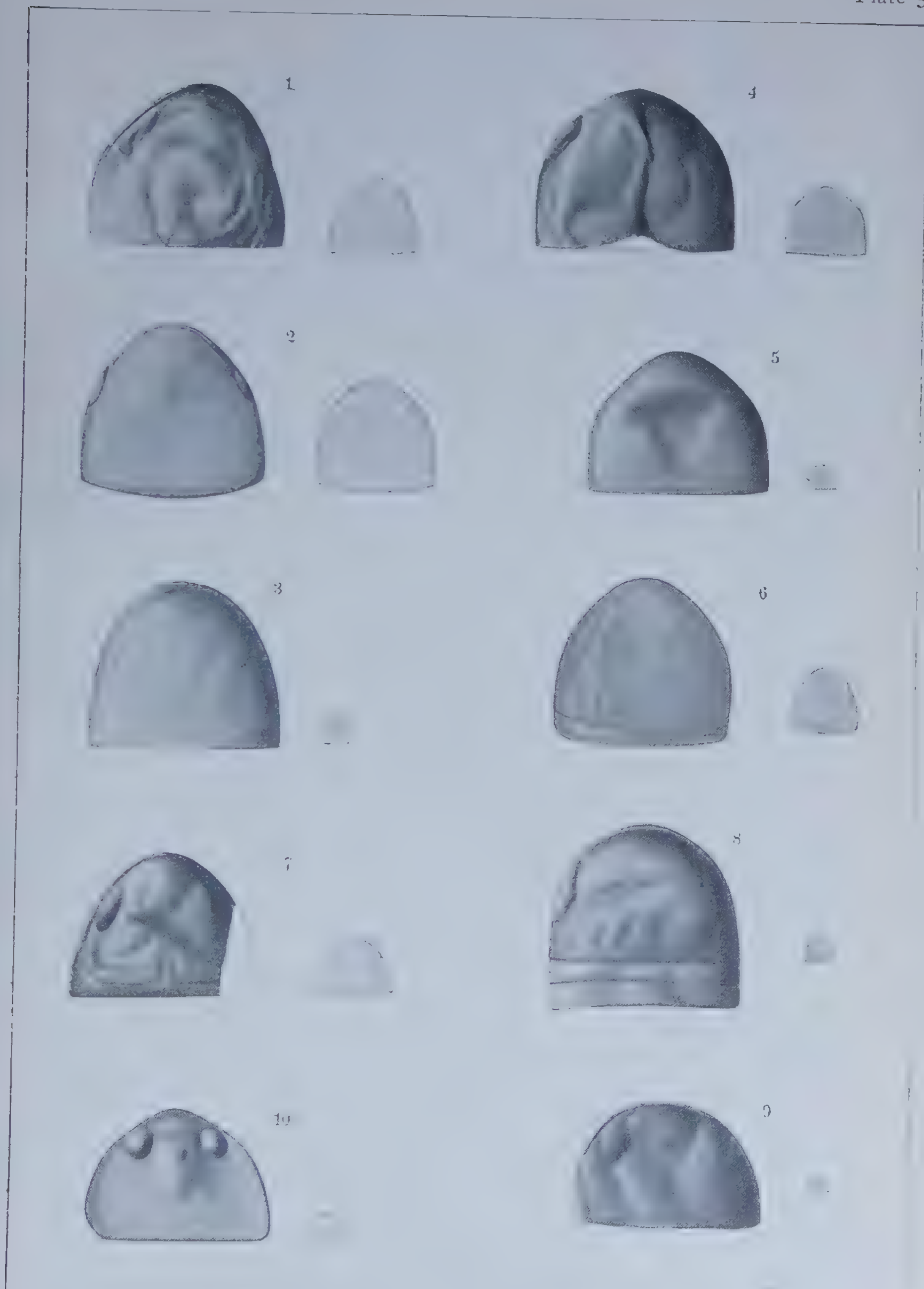
See plate 4

1-9 Head shields having for the most part the subtriangular elongate outline and marginal eyes characterizing the species H. socialis. In these details there is however some variation; in the very small heads represented by figures 3, 5 and 8, all trace of eyes is practically wanting. It is quite probable that the minute head shown in figure 9 with its large intramarginal anterior eyes and ocellar mound represents the following species. Actual variations in position of the compound eyes in this species are apparently from submarginal and marginal to intramarginal.

Eurypterus ? cicerops nov.

Page 307

10 This singular head shield has the lobes of the compound eyes small, circular, greatly elevated and anterior with a definite development of the ocellar mound. The body is regarded as a young stage of a species whose adult form is not yet recognized.



G. S. Barkentin, del.

PLATE 6

Eurypterus myops nov.

Page 306

1-5 Heads of this species, showing the quadrangular form and some slight variation in the position of the large approximate eyes. Figures 3-5 are natural size.

Figure 6 may possibly belong to this species, and represent a young phase with the eyes well toward the margin.

Pterygotus ? otisius nov.

Page 308

7 A quite distinct form of head with anterior almost marginal eyes, ocellar mound and smooth surface.

Eurypterus or Pterygotus

8 Eye of a large specimen.

Stylonurus ? sp.

Page 308

See plate 7

9-11 All these segments show a lobation which seldom occurs in the Eurypterids but is best exemplified in the species of Stylonurus described by Fr. Schmidt [*see* p. 309]. The large segment in figure 11 indicates how a slight lateral shearing has developed this lobation into a sharp division line (suture?) at the right, while from the same line of weakness at the left the whole lateral moiety of the segment has been completely distorted.

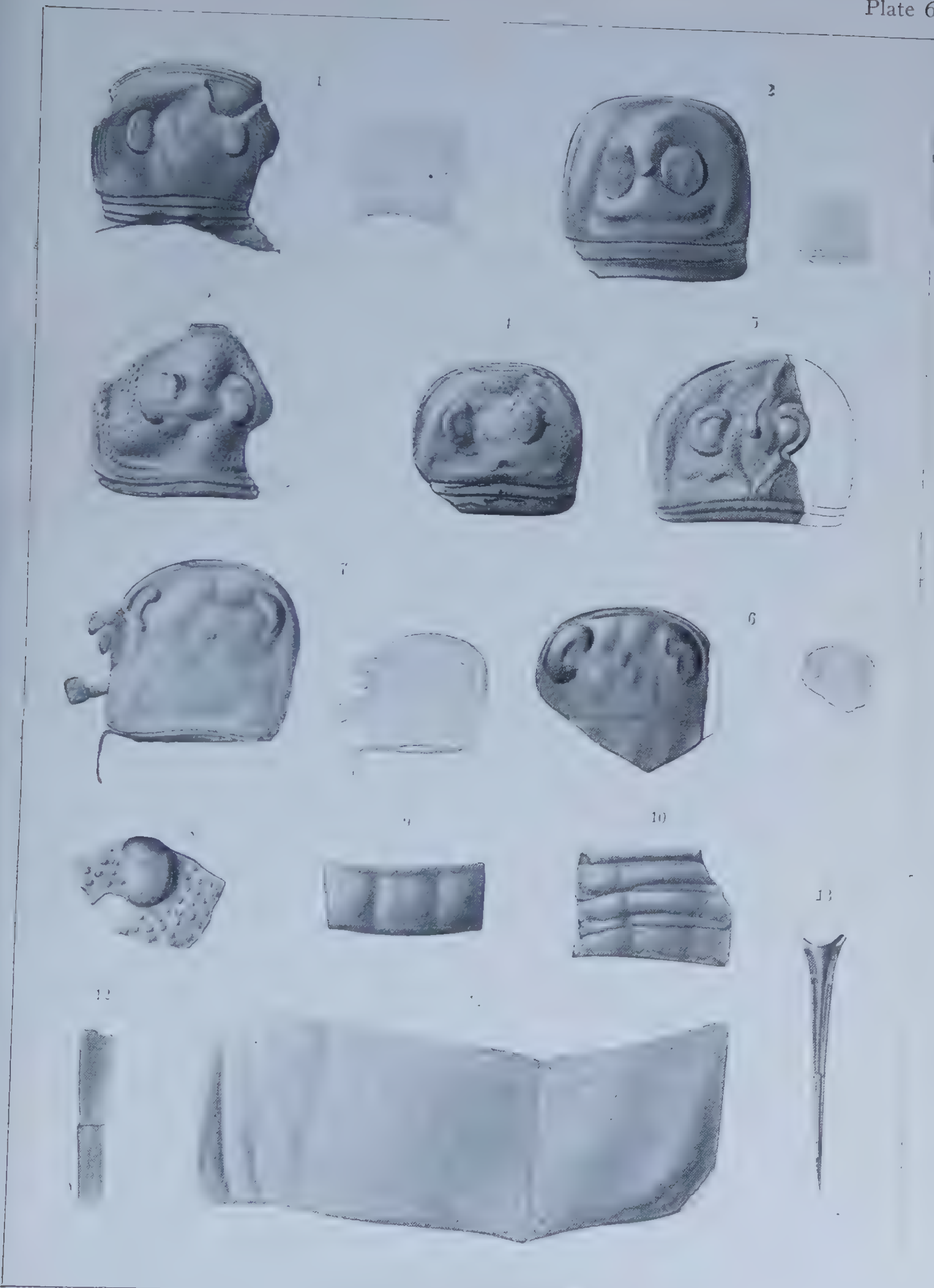
12 Two long slender leg joints.

Phyllocarida

Page 309

See plate 8

13 The middle spine or telson of a phyllocarid.



G. S. Barkentin, del.

PLATE 7

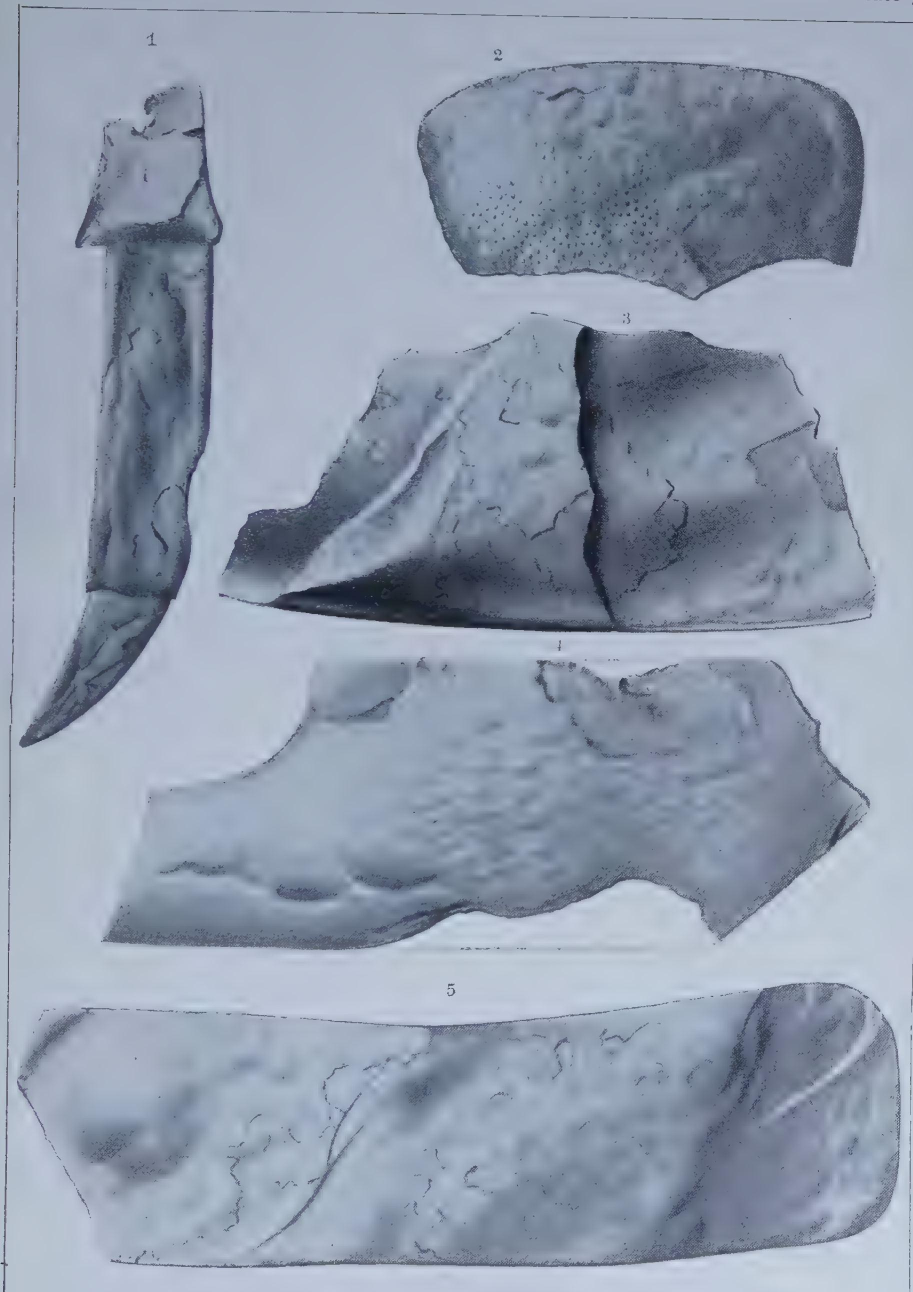
Stylonurus sp.

Page 308

See plate 6

1 The terminal joints of the long posterior or fifth foot.

2-5 These are parts of segments or shields which will convey an idea of the dimensions attained by some of these merostomes. All have been more or less distorted by shearing but such fragments are common in the shales and indicate the abundant presence of these large animals in the fauna. They all may be regarded as belonging to the genus Stylonurus.



G. S. Barkentin, del.

PLATE 8

Segments and joints

of **Eurypterus, Hughmilleria, etc.**

1-8 These are all natural size drawings and 1-4, 7 appear to be sternites, the transverse suture being clearly marked in all. Figure 2 is a second sternite and bears the mark of the opercular appendage. Figure 6 is a series of abdominal tergites; 8 the half of a sternite (second?) with very unusual surface markings.

9 Two joints of a slender grooved appendage (Stylonurus) with denticulated ridges.

10 Gnathobase of a swimming foot.

11 The filamentous terminal joints of one (or two) large endognathites, probably of Stylonurus.

Phyllocarida

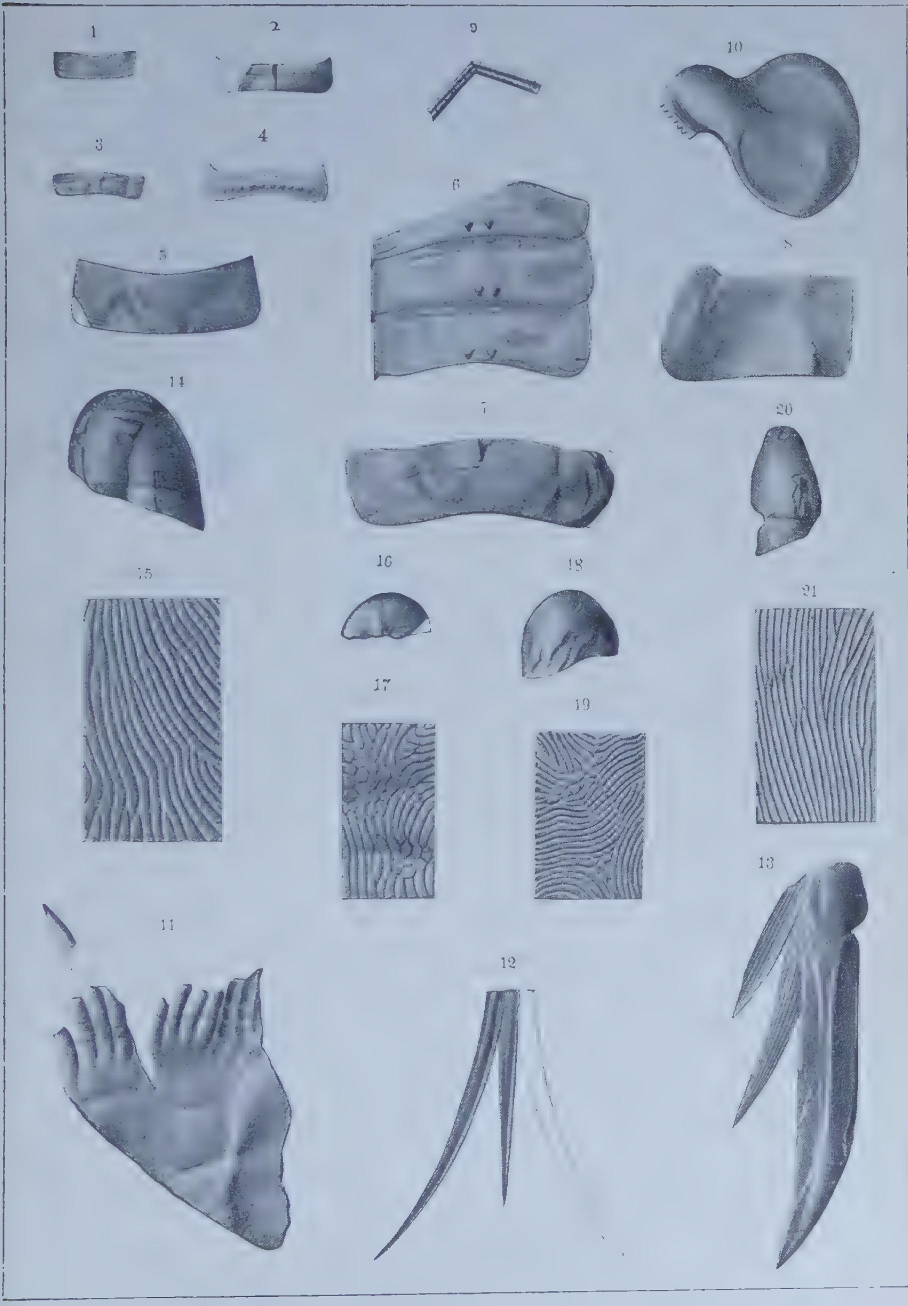
Page 309

See plate 6

12 Telson and cercopod. x2

13 The same parts of a very distinct species with heavy and long central spine with short lineate cercopods.

14-21 A series of fragments which afford no definite clew to the original form of the bodies, but the enlargements accompanying each show the very peculiar character of the surface engraving. There is no reason for assuming any association between these bodies and the tail spines already referred to, but it is fairly certain that they can with entire safety be regarded as Phyllocarid remains. They have been found only in the gray shale beds lying at the top of the grit and black shale series.



G. S. Barkentin, del.

View of the Grimes gully, Naples, N. Y., showing the locality (X—X) of the tree here described

A REMARKABLE FOSSIL TREE TRUNK FROM THE MIDDLE DEVONIC OF NEW YORK

BY

DAVID WHITE

The fossil trunk which forms the subject of this description lies on a large slab mounted in the eastern bow window of the Geological Hall of the New York State Museum. The specimen, which is over 3.25 meters in length, is extraordinary not only for its perfection, but also for the fact that it represents, so far as I am aware, by far the largest tree of its order yet found in Precarbonic rocks. But it is still more remarkable for the new light which it throws on the habit of growth, superficial features, and systematic affinities of one of the early forerunners of two great Paleozoic plant groups, the Lepidodendreae and the Sigillariae. It will be seen that its interest and importance as illustrating a stage in the development of the Paleozoic Lepidophytes (Lycopodiales) far overshadows its great value as a unique and most imposing specimen of a very ancient type of tree.

Source and age of the specimen

The specimen was discovered in 1882 by D. D. Luther, in the upper Devonic shale at the mouth of Grimes gully, about 1 mile west of Naples, N. Y. The shale has been described[1] as the "Hatch shale." It comprises the topmost division of the Portage group in that meridian of the State. The disentombment of the remains of the tree was completed under Dr J. M. Clarke's direction some years later, and a short announcement of its installation in the State Museum was published[2] in 1887.

As originally quarried the specimen is reported to have been about 5 meters in length to the point of outcrop in the side of the ravine. No evidence of branching was seen, and the branches, of which there probably were but few, were lost by the erosion of the shales during the cutting of the ravine. At the point of outcrop exposure the trunk is said to have been but 70 millimeters in width. At the time of mounting in the Museum during the absence of

[1] N. Y. State Mus. Bul. 63. 1904. p.33.
[2] Clarke, J. M. Science 225. 9: 516.

Mr Clarke the tree was unfortunately reduced to its present length to suit the dimensions of the embrasure at the side of the building. The fossil remains consist of the nearly completely flattened impression of the trunk, on a portion of which the carbonized cortex still lies. The matrix is a very fine grained blue shale.

The specimen is so important on account of the varying cortical features, some of which suggest most interesting relations to several groups of the upper Paleozoic Lepidophytes, as to merit description in more than usual detail.

Description of the trunk

In pointing out the characters presented by the Naples trunk attention will be given, in order, to (*a*) the rootlets; (*b*) the general features of the cortical topography including the form and relations of the leaf cushions or bolsters, which will be seen to combine forms characteristic of both *Lepidodendron* and *Sigillaria;* (*c*) the phyllotaxy; (*d*) the leaf scar, which illustrates a type peculiar to the Devonic and Lower Carbonic (Mississippian) Lepidophytes; and (*e*) the leaves. The general form, nomenclature and systematic classification of the tree will be considered later.

The aspect of the trunk as a whole is shown in the photograph one eighth the natural size, plate 1.[1] In the following plate diagram, plate 2, are shown the areas selected for illustration in natural size to indicate the details of various portions of the specimen.

As now mounted the basal section of the trunk, which is dilated like that of the royal palm, is 38.5 cm in width, while the width at the broken top is but 12 cm. The length is 338 cm.

Rootlets. The area imperfectly shown, natural size, in plate 3, figure 1, includes a portion of the lower periphery of the butt of the tree from which fragments of long ribbonlike rootlets stream downward. These rootlets, portions only of which are disclosed, are articulated at large areolate umbilicoid scars, a number of which, like those shown in figures 3 and 4 on the same plate, are still exposed though mostly somewhat distorted by pressure. These cicatrices (X) show the outer ring, corresponding to the attachment of the cortex, the inner ring representing the nerve sheath and the nerve trace itself. The similarity of these scars to the typical scar of Stigmaria will at once be recognized; and it may be added that

[1] On account of the size and position of the specimen it is impracticable to photograph the fossil as a whole. The trunk was first photographed in sections, natural size, and the latter were joined and then photographed as shown in plate 1.

Unfortunately the fossil lies in natural illumination from the right, so that the topography is reversed. The reader is therefore asked constantly to bear in mind that the light is from the right in all figures not specifically designated as otherwise illuminated.

the characters of the cuticle and axial impression of the rootlet agree equally well. In its present condition of preservation on the slab the flattened base of the trunk is subtruncate. It is therefore impossible to determine with certainty whether the tree was provided with the four radiate principal forking roots characteristic of the later Lepidodendreae and Sigillariae. However, since the need for support for so large a tree seems to demand the aid of some type of root we are justified in assuming that the trunk was originally supplied with a more efficient root buttress than the small rootlets now remaining; and since the latter appear to correspond in essential characters to the rootlets of the Carbonic Stigmaria, and since this type is known to be present in the Lower Carbonic, it becomes highly probable that the Naples tree was sustained by roots essentially Stigmarian in character. A notable feature of the Devonic trunk is the large size of the rootlets and areoles as compared with the size of the trunk.

Enlarged base. As shown in plate 1, the base of the trunk is very much swollen in a way suggesting the boles of the royal palm. Throughout the extent of this enlargement the cortex shows evident signs of expansion with the advanced growth of the tree by which the epidermis was probably ruptured and the original rows of leaf cushions were widely separated and displaced. This feature is well shown in plate 4, in the lower part of which, beginning just above the area shown in plate 3, figure 1, the cortical impression is seamed by irregular longitudinal and subparallel narrow ridges probably due to the presence of hypodermal strands. In the upper part of plate 4 the impression of the lower side of the trunk is marked in low rounded, ill-defined, and indistinctly rhomboidal prominences, between which lie the now widely separated and oblique rows of leaf cushions (P). The rupture of the distended cortical tissue between the at first oblique and then mostly vertical leaf cushion rows is more sharply defined a few centimeters higher[1] where, as illustrated in the lower part of plate 5, we have a cortical condition similar to that often presented in the dilated basal portions of the trunks of some Carbonic Sigillariae.[2] Whether the basal dilation of the trunk in the Naples tree was concomitant with a development of secondary (exogenous) wood, can not be determined in the absence of specimens so petrified as to show the internal anatomy. I am, however, inclined to believe that it may have attended a secondary growth.

[1]See plate 2.
[2]Similar seamed and welted phases of the distended and ruptured bark were described, though not properly, by Lesquereux as Ulodendron.

Formation of the leaf cushions in vertical rows. Traces of the leaf cushions, in distant, irregular and generally oblique rows may be seen down to within 5 cm of the basal periphery of the specimen. In passing upward they become more clearly defined, P, plate 4, on narrow ridges which, higher still, plate 5, become more prominent and more distinctly linear as well as more numerous. Accompanying the rapid contraction of the bole in passing upward the leaf cushion rows become more regular and closer, as is shown in plate 5. The zone of plate 5, 25 to 50 cm above the base of the trunk, is the region of most rapid increase in the number of the cushion rows, as well as of rapid decrease in the diameter of the trunk. The introduction of new rows of leaf cushions, i. e. of new ribs, is distinctly shown at R on plate 6, in which we have about 23 rows at the upper end within a longitudinal zone embracing but 10 rows at the lower border. At the level of the upper border of the plate the impression shows 44 rows on one side of the stem. It is difficult to ascertain exactly the number of rows on the lower portion of the trunk; but on the level of the middle of plate 4, about 45 cm lower, there appear to be but 16 or 17 rows on the impression.

Region of sigillarioid leaf cushions. The upper part of the area in plate 5, and the area situated about 5 cm higher, shown in plate 6, exhibit the passage from the distant and irregular leaf cushion row to the arrangement of the cushions in close, parallel, vertical rows, each occupying the medial zone on the highly convex surface of a longitudinal rib, an arrangement characteristic of the ribbed Sigillariae. It may further be noted that in the upper part of this plate the leaf cushions, S, occupying the greater portion of the width of the rib, are, in the same row, separated by well defined, narrow, transverse furrows which effect a partial segmentation of the rib, while the ribs are separated by sharply defined, narrow, angular furrows, thus presenting the characteristics of the favularian section of the great Rhytidolepis group of the Carbonic Sigillariae, with the exceptions of the differences in the leaf scar itself, and the phyllotaxial angle. The similarity to the ribbed Sigillariae is further seen in the parallel hypodermal strands, which in the partially macerated portions of the cortex are seen to traverse the slightly zigzag intercostal furrows, H, plate 6.

From the level of the area shown in plate 6, the distinctly sigillarioid type of cortex with the leaf cushions on narrow longitudinal ribs continues for some distance, while the ribs themselves become

somewhat narrower so as to emphasize the favularian aspect as is illustrated at about 80 cm from the base of the trunk in plate 7, figure 1. In this area the lateral cicatricules (parichnoi) of the leaf scar are unusually clear in subepidermal impression, where they appear to unite below in a narrow horseshoe form.

The surface shown in plate 7, figure 3, is included in a fragment of the counterpart impression of a portion of the trunk, at a level about 90 cm from the base. It illustrates[1] the distinctly vertical alinement of the leaf cushions, which are becoming elongated in an obovate-elliptical shape, the form of the leaf scars themselves, and the hypodermal strands seen in the partially macerated upper central area. The small portion, at a point a little lower on the trunk, shown in figure 1, includes an area in which the ribs are less macerated and well rounded, with but slight constriction between the leaf cushions.

In plate 8 is shown, natural size, a portion of the actual carbonaceous residue of the trunk itself. The specimen, the impression of which is in part shown in plate 7, figure 3, comes from near the center of the trunk and is but 4 mm thick along the middle, the thinner, fragile, carbonaceous borders being lost. It is, however, particularly interesting as showing the outer surface of this portion of the trunk. The outlines of the leaf cushions, which are observed to be more prominent near their upper ends, are well defined, while the leaf scars are in most cases recognizable. It is to be noted that the cushions are nearly bilateral though the elongation approaches the lepidodendroid form and the spirality of arrangement is distinct in the area on the upper right.

Region of lepidodendroid form of leaf cushion. It has been seen that in the lower areas examined the leaf cushions are alined on very distinct longitudinal costae, from which they slightly protrude. However, in passing upward we find a gradual change to a leaf cushion form and relation more nearly characteristic of Lepidodendron. Even at some distance below the middle of the fossil the compressed cushions often present a lepidodendroid form near the border of the stem. An example of this is shown in plate 7, figure 2, from an area but 85 cm from the base, where we find, on the left, closely placed, indistinctly rhomboidal impressions of cushions which are more clearly spiral in arrangement and which appear to overlap somewhat obliquely in the longitudinal sense. These approach a Bergeria stage; but the cushions on the right, in the medal zone of

[1]This figure is shown in light from the left.

the fossil, appear narrower and are plainly in vertical series on ribs. It is probable that the form of the lepidodendroid cushions in this area is in part due to obliqueness of compression as will later be explained.

From a hight of 80 cm upward the lepidodendroid form of cushion is constantly more or less in evidence, first along the borders of the fossil, and later throughout its width. The marginal occurrence of rhomboidal cushion impressions is also illustrated, in plate 9, figure 1, from an area 150 cm above the base, where again we find the medial costae relatively narrow, though the cushions, especially on the right near the borders, are broader and slightly overlapped obliquely in the same vertical row. The width of the medial rows is evidently foreshortened by lateral pressure in the process of the flattening of the trunk. This foreshortening indicates the destruction of the inner tissues of this part of the trunk before the compression of the outer cortex. A discontinuity of the cushions and an absence of lateral symmetry are apparent on the right of the photograph, which represents nearly the entire width of the fossil at this point. The small area, shown in plate 9, figure 3, about 10 cm higher than that in figure 1, is characterized by broad and unusually compact cushions with more elongated leaf scars. In outline the cushions are lepidodendroid and wholly without costate arrangement, although ill-defined ribs, largely the result of pressure, appear near the median line of the stem.

In that portion of the trunk above 175 cm from the base the lepidodendroid form of leaf cushion is overwhelmingly dominant though narrow medial costation is still to be seen for some distance farther. The surface at 210 cm shown in plate 9, figure 2, presents a still more elongated and asymmetrical obliquely overlapping leaf cushion, whose spiral arrangement is, for the most part, far more distinct than the vertical alinement. The cushions shown in figure 2, like those seen at 270 cm in plate 10, figure 2, and especially at 285 cm in plate 10, figure 3, are distinctly lepidodendroid even to a slight basal truncation, and are practically without costate arrangement. They represent the common Devonic lepidophytic type, referred by all authors to the genus Lepidodendron.

Near the top of the fossil the Lepidodendron form of leaf cushion is present even along the median line, as may be noted

in the segment extending to 325 cm shown in plate 11. In this region the leaf cushions are elongated, close, indistinctly fusiform, more prominent at the upper end, asymmetrical, and distinctly spirally arranged. In other words, so far as concerns form and topography the leaf cushion is nearly typical of Lepidodendron.

Knorria condition of cortex. An interesting feature presented by the Naples tree is the existence of a region of Knorria condition[1] at about 225 cm from the base. This is shown in an area, plate 10, figure 1, in which, on the right, we see the broken remains of the elongate, narrow-rounded nerve trace sheaths passing nearly erect upward and outward to the underlying and concealed surface of the bark, those below being imbricated over those emerging higher in the trunk. The fragments still adhere to the impression of the outer cortex, their broken, inner ends projecting downward. Where removed, a little to the left of the middle, we see the narrow leaf costation, which toward the border, still further to the left, yields to the lepidodendroid type of cushion. It will be noted that the sheath casts appear to widen upward to the full breadth of the rib. In the area partially shown in figure 2, in the same plate, we see the expression of these sheaths very obliquely emerging to the narrowly rhomboidal or fusiform cushions, and passing to the leaf scars themselves. The Knorria stage or structural type is known in the cortices of Lepidodendron, Bothrodendron, and the Asolanus group, or Subsigillariae.

Phyllotaxy of the tree. The seemingly anomalous occurrence of the favularian (sigillarian) costate type of leaf cushion in one part and of the lepidodendroid type in another part of the same individual trunk finds its explanation in the Knorria stage just described and in the character of the disposition (phyllotaxy) of the leaf cushions on the trunk.

The plan of the leaf cushion distribution is well shown in figures 1 and 2, plate 7, or any of the other areas in the lower part of the trunk. In the portions cited we find a very distinct alinement in vertical rows, a fairly clear horizontal alinement, and less conspicuous oblique rows at an angle of approximately 45°. The scars alternate in the transverse rows which are at an angle averaging very nearly 90° with the longitudinal

[1]The name Knorria was applied to a Lepidodendron cortex in which, as the result of partial maceration of the tender tissues of the inner and middle cortexes, the casts of the leaf trace sheaths, spirally arranged and usually very oblique or appressed, are shown as imbricated scale points, in aspect suggesting spirally placed erect slivers. It was at first regarded as a valid genus, but was later recognized as merely a condition of preservation of certain lepidophytic stems.

rows; and the orthostichy is therefore approximately 90°. Lines connecting the centers of any group of four proximal scars will form a rectangle in which the hypothenuses are vertical and horizontal. The passage from the favularian to the lepidodendroid type of leaf cushion arrangement is primarily due to the combined effect of the rapidity and direction of growth on the one hand and the phyllotaxy on the other.

In the lower portions of the trunk, in which the ribbed type of cortex is most strikingly developed, plate 6, the cushions in the same vertical row are very close as the result of relatively slow linear growth. At the same time the lateral expansion or thickening of the trunk has widely removed the rows, especially near the base, as seen in plate 5. Thus, in the plate just cited the leaf scars may be but 3 mm, or less, distant from center to center in the same row, while at 90 cm from the base they are 7 mm distant. Near the top they become about 11 mm distant. At the same time, in passing upward we find the ribs growing narrower, and the vertical rows coming more closely together, not merely as the result of the introduction of new rows, but by reason also of greater linear growth as compared with the transverse increase in the size of the tree. As the cushions in the vertical rows become more distant and the lateral cushions crowd closer we find the rhomboidal type appearing near the periphery of the impression, and later in the median zone.

Referring again to the Knorria stage illustrated in plate 10, it will be seen that the narrow ribs correspond to the vertical rows of nearly erect and imbricated nerve-trace sheaths whose more resistant structure makes their presence known even when the outer cortex and cushion tissue is but partially shrunken, as in figure 2 of the same plate. When the hollow cortical cylinder was flattened and the median portion of the fossil foreshortened by lateral pressure, the rows of more rigid sheaths undoubtedly controlled the clear alinement and strong topography of the median ribs, whose present narrowness is due to the lateral pressure. There is little room for doubt that the presence of ribs in the median portion of the upper part of the trunk is chiefly due to the resistance of the nerve sheaths. No doubt they also contributed to the prominence and rigidity of the costae in the lower part of the trunk. Where the pressure was oblique to the surface, as near the lateral borders in the areas

shown in plate 7, figure 2, or plate 9, figure 1, the obliquely ascending sheaths were crowded somewhat to the side so as more readily to obliterate the longitudinal seriation.

The transition from the distinctly sigillarian arrangement of the leaf cushion to the dominantly lepidodendroid type is concomitant with the relative increase of the vertical distance between the leaves in the same row on the trunk; and it is consequent to the more rapid longitudinal growth of the tree by which the leaves are farther removed from one another in the vertical sense, and the more distant sheaths are not compactly overlapped so as to form a continuous row or ridge.

The rectangular phyllotaxy seen in the Naples tree is in general characteristic of the Devonic Lepidophytes, and is present also in the Carbonic Bothrodendron (Subsigillariae). When the slow longitudinal growth, without great expansion of the cortex, has brought the leaf scars into very close relations vertically, the leaves have in some cases been described as verticillate.[1] Continuous impressions of the escaping nerve-trace sheaths in longitudinal rows, all the more distinctly defined through the partial maceration of the softer tissues so as to form narrow ribs, are also to be observed in many of the fragments reported as Lepidodendron gaspianum. In the higher Carbonic Lycopods the rectangular phyllotaxy or pseudo-verticillate arrangement is seen in the Sigillariae, and in the strobilar axis of Sigillariostrobus, or even in Lepidostrobus.

Leaf scar. The leaf scar of the Devonic fossil, like those of the Carbonic Lepidodendron and Sigillaria is placed on the upper part of the leaf cushion, and on the most prominent area of the latter. In general it is very regular in form, slightly obovate, or oval-obovate, rounded below and slightly cordate at the upper border. Illustrations from the lower or sigillarioid portion of the trunk are shown in plate 6 at S, while examples higher in the specimen are seen in plates 7, 8 (in relief), and 10.

Within the sinus at the upper edge of the leaf scar, plate 10, figure 4, is a fairly distinct ligular pit, similar to that seen in the Carbonic Lepidophytes. It is interesting to find the ligule, so characteristic of the Paleozoic predecessors of the Lycopodiales, already present in the upper Devonic type.

The passage of the nerve trace, or vascular bundle, to the leaf is marked by a punctiform scar slightly above the middle

[1] e. g. Lepidodendron corrugatum var. verticillatum from the lowest Mississippian.

of the leaf scar. On either side of the nerve trace, and at but little distance within the lateral border of the scar, is situated a vertically elongated and slightly crescentic cicatricule, the cross-section of a loosely parenchymatous transpiratory tract. The cicatricules (parichnoi) are slightly hooked inward at the upper ends, figure 4, while in the subepidermal impression they are found to coalesce in an ovate figure embracing the nerve trace.[1] No distinct trace of appendages has been observed.

By the characters of the leaf scar the Naples tree is more closely related to Bothrodendron and Sigillaria than to any representative of the Lepidodendreae. The rounded form of the scar suggests Bothrodendron, though the vertically elongated parichnoi are comparable only to those of certain Sigillariae, especially the Rhytidolepis group. By its combined characters the scars of the Devonic trunk differ however, from both Bothrodendron and Rhytidolepis, the two oldest representatives of their respective groups.

Leaves. The leaves of this type of tree appear to have remained attached for a long time, since some of them are persistent as low as but 70 cm from the base of the trunk. As shown on the left border in the lower middle, at L in plate 11, and in figure 3, plate 10, they are short, not over 3 cm in length, very narrow, and somewhat lax. In this fossil which comprises the older portion of the trunk they stand out at nearly a right angle, or are even slightly reflexed. The base of the leaf is conically enlarged to coincide with the leaf scar, and this portion seems to have been largely composed of soft and very perishable tissue. The nerve trace is clearly marked, while on the sides there is evidence of the boundaries either of parichnoian zones or of a large sheath which may be traced in gradually converging lines nearly to the apex.

The small size, usually rather lax form, enlarged base, and persistent habit are in general characteristic of the leaves of the Devonic group to which the Naples tree belongs.

General relations of the tree

The examination of the magnificent specimen from Naples shows that although it appears to represent a synthetic type antecedent to the later Paleozoic Lycopodiales it is none the

[1] In many of the subepidermal impressions, plate 7, figure 3, the prominent cicatricule strongly resembles the corresponding sigillarian homologue once generically described as Syringodendron.

less a well developed Lycopod, and not the most simple in its organization. It is even possible that it developed secondary wood in the dilated butt.

Its base was provided with stigmarioid rootlets and was presumably supported by some type of stigmarioid root, though the other contemporaneous Devonic material yet found does not justify the assumption that it was associated with the long roots typical of Stigmaria.

We have seen that the leaf cushion form in the lower portion of the trunk is characteristic of the favularian ribbed Sigillariae, while that higher on the trunk is equally characteristic of the Lepidodendreae. The leaf cushions differ, however, from Lepidodendron by the phyllotaxy; from Sigillaria by their narrowly rhomboidal form; and from Bothrodendron by the development of ribs and definite leaf cushions which, in conjunction with the relative linear or lateral growth of the axis, results respectively in the lepidodendroid or the sigillarioid aspect of cortex.

The costae are due to the vertical alinement of the cushions and the presence of a resistant nerve trace sheath which traverses the cortical tissue and which becomes imbricated in a longitudinal ridge when the surrounding tissues have shrunken. Partial decortication displays these sheaths as a Knorria condition, a condition found in Lepidodendron, Bothrodendron and Asolanus (Subsigillariae).

By its leaf scars the Naples tree is most closely related to Bothrodendron and the Rhytidolepis Sigillariae. It differs from the former by its elongated parichnoi and from the latter by its obovate form. On the whole it is nearly intermediate to the two groups.

The leaves of the fossil trunk are in character nearest those of Bothrodendron, especially in respect to their basal dilation, though in aspect they closely resemble those of certain Lepidodendra. The persistence of the leaves is characteristic of the Devonic group to which the trunk belongs.

Although this group has nearly always been described as Lepidodendron, its special resemblance to the latter is confined to the development of narrowly rhomboidal prominent leaf cushions and to the habit of the leaves. Bothrodendron sometimes exhibits distinct rhomboidal leaf cushions[1] in the small twigs though its cortical surface is flat and shagreened in the larger members. In the Sigillarian group the nearest relatives

[1] See Weiss & Sterzel. Die Gruppe der Subsigillarien. 1893. pl.1, fig. 3.

appear to be among the Rhytidolepis and favularian species. Taking into account the importance of leaf scar characters it is probable that the Naples tree is more closely bound to the former (Rhytidolepis) which seems also to have been geologically the earlier to appear. With this and Bothrodendron (Cyclostigma) it would seem to be nearly equally allied, its connection with the latter being possibly the more intimate.

When living the tree was probably nearly a foot in diameter at the enlarged base. From this it rose straight, tapering fast at first, and then very gradually. It has already been noted that no branches were present up to the end of the fossil at a hight of 5 meters where it measured but 7 centimeters in width. It seems probable, therefore, that branching was rare. We may conceive of the tree as gently tapering and finally dichotomizing in slender, arching, and very distinctly forked, gracefully drooping branches to which the open, short, persistent leaves imparted a plumose aspect. It is possible, however, that the branches may have been clambering or sprawling, rather than pendent in habit.

Unfortunately neither the specimen in the Museum nor its associates have afforded any petrified portions by which satisfactorily to ascertain the features of their internal anatomy. We may, however, I believe, conclude that a periderm situated in the outer cortex and capable of permitting a growth of exogenous bark was present. If there was any development of an exogenous or secondary growth of wood in the trunk, as seems possible, it was probably confined to the region of the dilated base.

Systematic position and name of the fossil

Fragments of the impression or of the counterpart of the fossil trunk were sent by Dr Clarke, the State Paleontologist, to Sir William Dawson, by whom they were identified as belonging to the species described by Rogers[1] from the Devonic of Pennsylvania as Lepidodendron primaevum. As to the specific identity of the two plants there is little doubt, and the specific term, primaevum, should be attached to the New York fossil, though it can not be retained in the genus Lepidodendron.

The Naples tree differs generically, as we have seen, from all the Carbonic Lycopod groups by the peculiar combination

[1]Geol. of Pa. 1858. v.11, pt 2, p.828, fig. 675.

of leaf cushion characters and arrangement, by the form and details of its leaf scars, and by its persistent small leaves which are more or less distinctly conical at their bases. Comparison of the fossil with other and less imposing fragments of Devonic Lycopods shows it to be one of the more highly developed representatives of a fairly distinct archaic group foreshadowing the later genera Bothrodendron (Cyclostigma), Sigillaria, Lepidodendron, and Lepidophloios. Among the members of this ancient group is the plant from the Devonic of New York figured by Vanuxem[1], and later named[2] Sigillaria vanuxemi by Göppert in his great work on the *Flora of the Transition Series*. The present repository of Vanuxem's type specimen is not known to me and I have therefore not been able to consult it. However, the collection of the State Geological Survey contains a similar specimen combining the lepidodendroid and sigillarioid forms of leaf cushion and probably belonging to the same species. To the Vanuxem plant, with which the Naples tree is certainly congeneric, Mr Kidston,[3] the distinguished British student of Paleozoic plants, has given the special generic name Archaeosigillaria.

After the examination of the greater part of the lepidophytic material from the North American Devonic I am convinced that by far the greater number of the forms described as Lepidodendron from the Middle and Upper Devonic of this continent are referable to the genus Archaeosigillaria. It should be noted, however, that the name applied by Professor Kidston is possibly preoccupied by Protolepidodendron, earlier proposed by Krejči.[4] The generic relation of Protolepidodendron scharianum, the type of the genus, to Archaeosigillaria is at present uncertain since Krejči did not illustrate his specimens, and the later publications by Stur[5], and by Bernard and Potonié[6] leave doubt as to whether Krejči's original specimen is not characterized by bifurcation of the leaves. The question of the generic nomenclature will be discussed more fully in a later paper treating in a somewhat detailed form many of the lepidophytic types from the Devonic of the eastern United States.

[1]Geol. N. Y. 3d Dist. 1842. p. 184, fig. 51.
[2]Foss. Fl. d. Uebergangsgebirge. 1851. p. 200.
[3]Nat. Hist. Soc. Trans. Glasgow. 1901. n.s. v. 6, pt 1, p. 38.
[4]Sitzb. k. böhm. Gesell. Wiss. 1879. p. 203.
[5]Sitzb. k. Akad. Wiss., Wien, Math. Nat. Cl. 1881. v. lxxxiv. Abth. 1, p. 333.
[6]Fl. Dév. Etage H de Barrande. 1905. p. 40.

Whether or not the Bohemian and Naples types are congeneric, I do not hesitate to place them in the same ancestral group, though recognizing in Protolepidodendron scharianum a form probably more primitive and ancient than Archaeosigillaria primaeva. This group, which contains the oldest known Lepidophytes, appears to be of family rank and may appropriately be given the family name Protolepidodendreae.

PLATE 1

PLATE 2

Fossil trunk of the Naples tree, Archaeosigillaria primaeva, in the State Cabinet of Natural History. Photographically reduced to 1/8 the natural size.

Diagrammatic outline sketch, in the same reduced size, of the fossil, showing the relative positions of the rectangular areas illustrated in natural size in the following plates, the numbers of which are indicated by bold-faced type.

The distances, in meters, from the base of the trunk are shown in smaller numerals on the right.

FOSSIL TREE

Plate 1

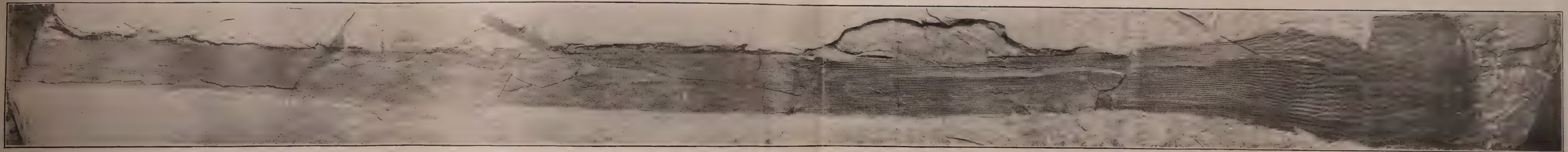


Plate 2

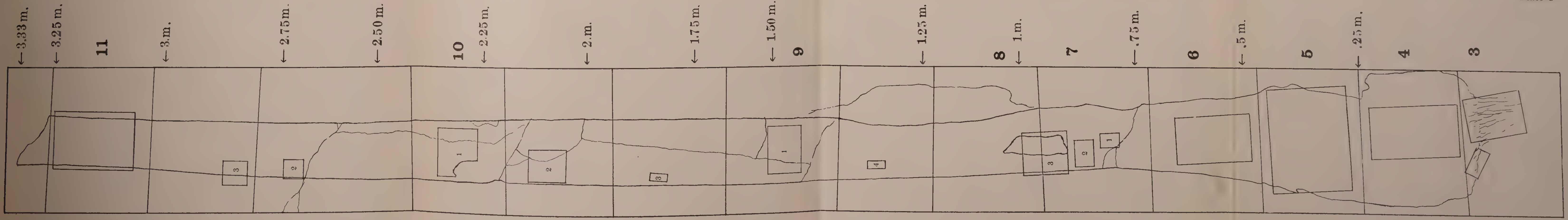


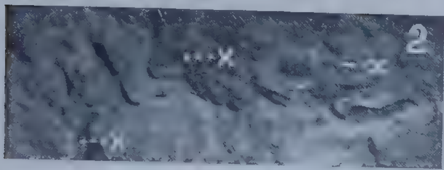
PLATE 3

Figures in natural size; lighted from the right

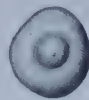
1 Portion of the truncate base of the fossil trunk, bearing scars (X) of the typical Stigmaria from which slender, collapsed, ribbonlike rootlets stream downward in the shale matrix. The latter, which agree in superficial characters with the Carbonic forms, are seen in plate 1 also, proceeding directly from the truncate base, no large bifurcating roots being shown in the specimen.

2 Small area showing stigmarian cicatrices (X) more distinctly.

3, 4 Details of stigmarian cicatrices, slightly enlarged.



3



4

PLATE 4

Natural size; lighted from the right

Surface of area just above base [*see* diagram, pl. 2, no. 4], showing greatly dilated cortex, seamed, and marked by very distant and oblique though irregular rows of leaf cushions (P), the individual cushions being very close, serially, in each row. The irregularly rhomboidal depressions between the leaf cushion rows are characteristic of the lower part of old trunks of Sigillaria and Lepidodendron.

FOSSIL TREE

PLATE 5

Natural size; lighted from the right

Area, including nearly the entire width of the impression, about 5 cm above that shown in plate 4. The impressions of the leaf cushion rows are becoming more regular and distinctly longitudinal, while the number of rows is increased by the introduction of new ones. The individual cushions are less compactly alined in each row near the upper end of the area here shown. This is the region of rapid contraction above the enlarged base of the tree. [*See* pl. 2, 3]

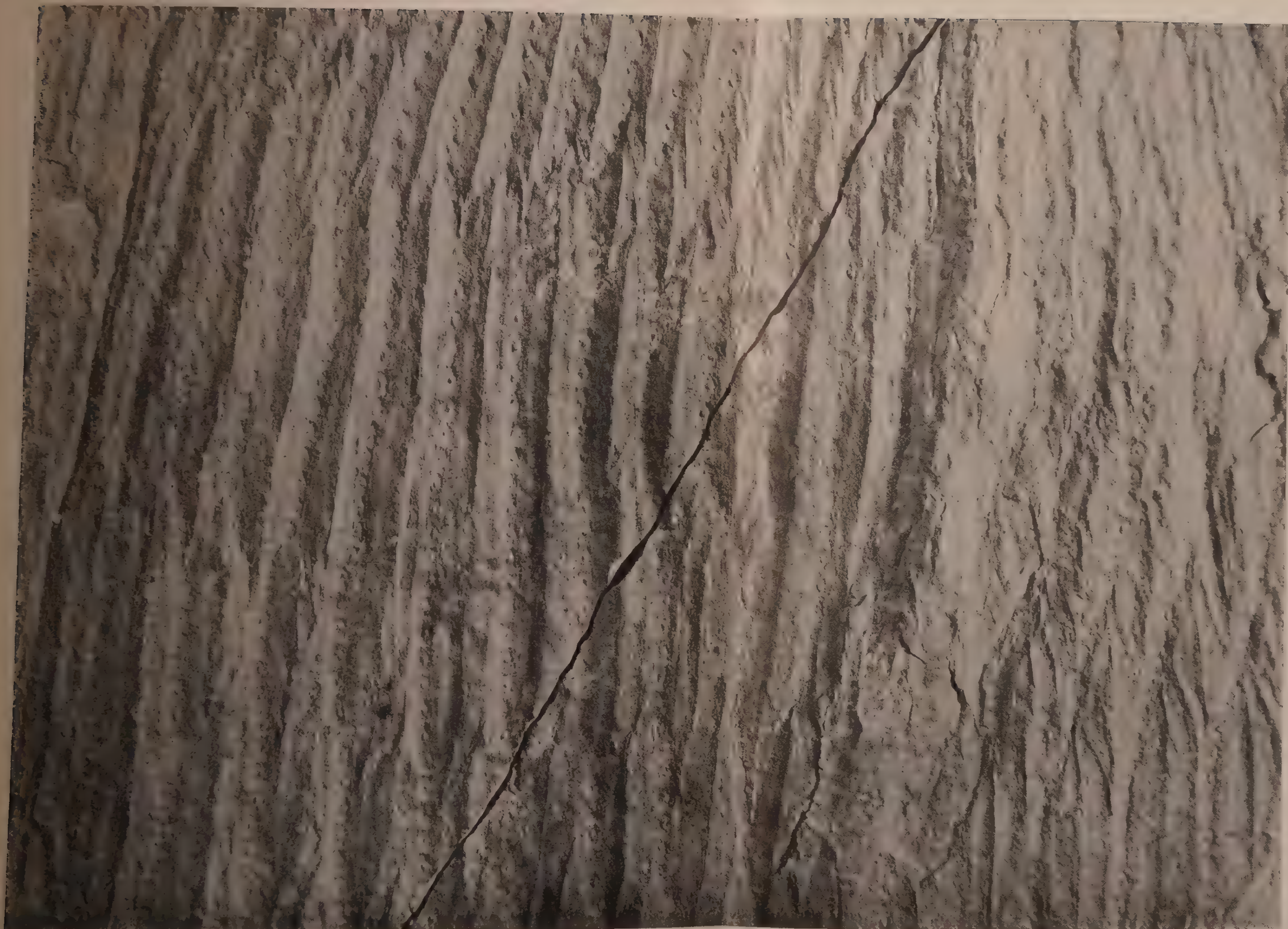


PLATE 6

Natural size; lighted from the right

Portion of the impression of the trunk about 5 cm above that shown in plate 5. The leaf cushions are borne in sigillarian arrangement on narrow ribs, the intercostal furrows (H) being slightly zigzag, as in the section Favularia. New ribs (R) appear at various points. The leaf cushions on the left are favularian in aspect, and, though the impression is subepidermal over portions of the area, the outlines of the obovate or oval leaf scars (S) are seen at many points.

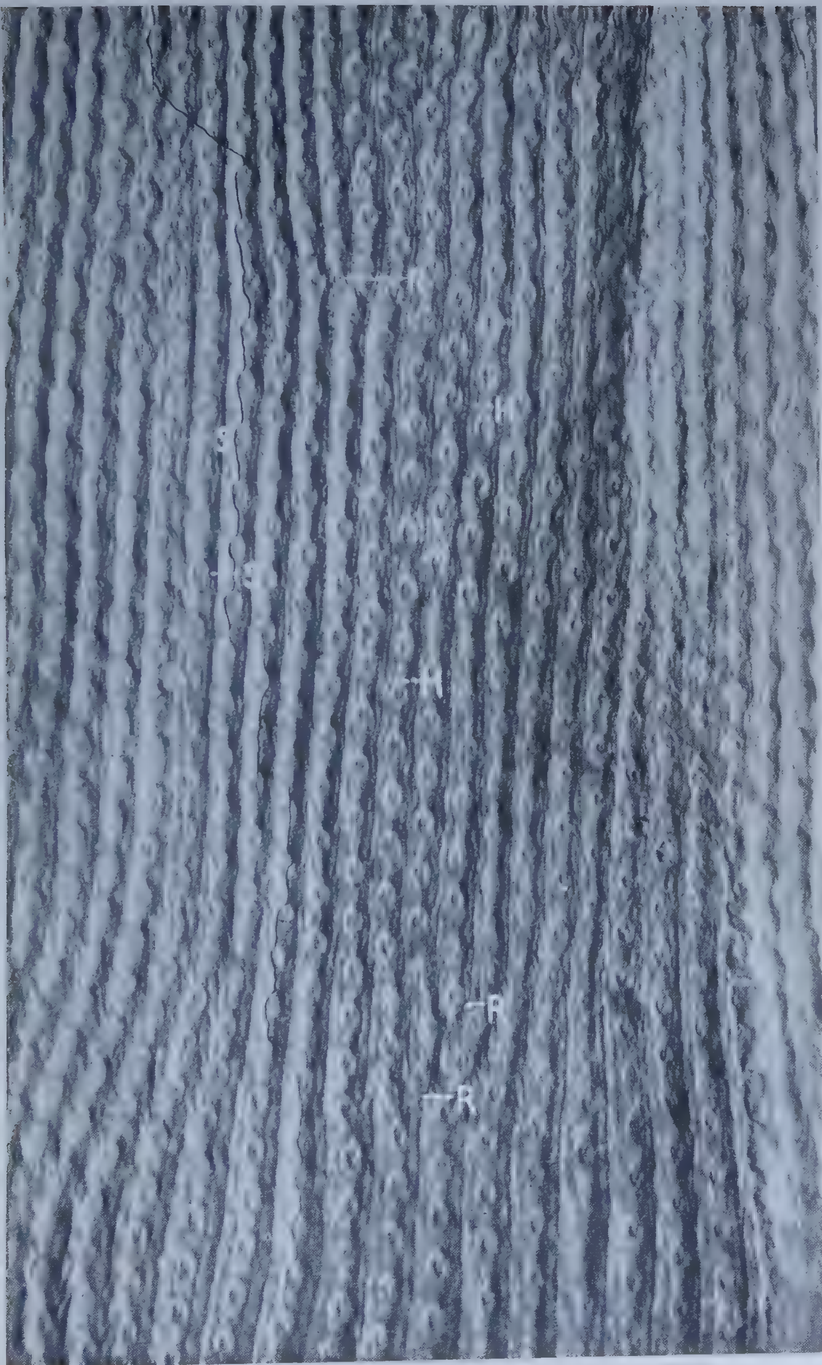


PLATE 7

Figures in natural size; figures 1 and 2, lighted from the right, figure 3, from the left

1 Surface with narrowly rounded longitudinal leaf cushion ribs; about 80 cm from the base of the tree.

2 Detail from area, a little higher, in which the cushions are in a distinctly costate arrangement on the right (near the middle of the stem), though on the left they assume a rhomboidal form, an aspect like those of Lepidodendron. The leaf scars, including the parichnoian cicatricules, are more distinct on the ribs, whose sharp configuration is probably due in part to lateral pressure.

3 Fragment of the impression of the counterpart, or upper side of the stem, at about 90 cm above the base, showing favularian cushion rows, with traces of hypodermal strands along the intermediate furrows.

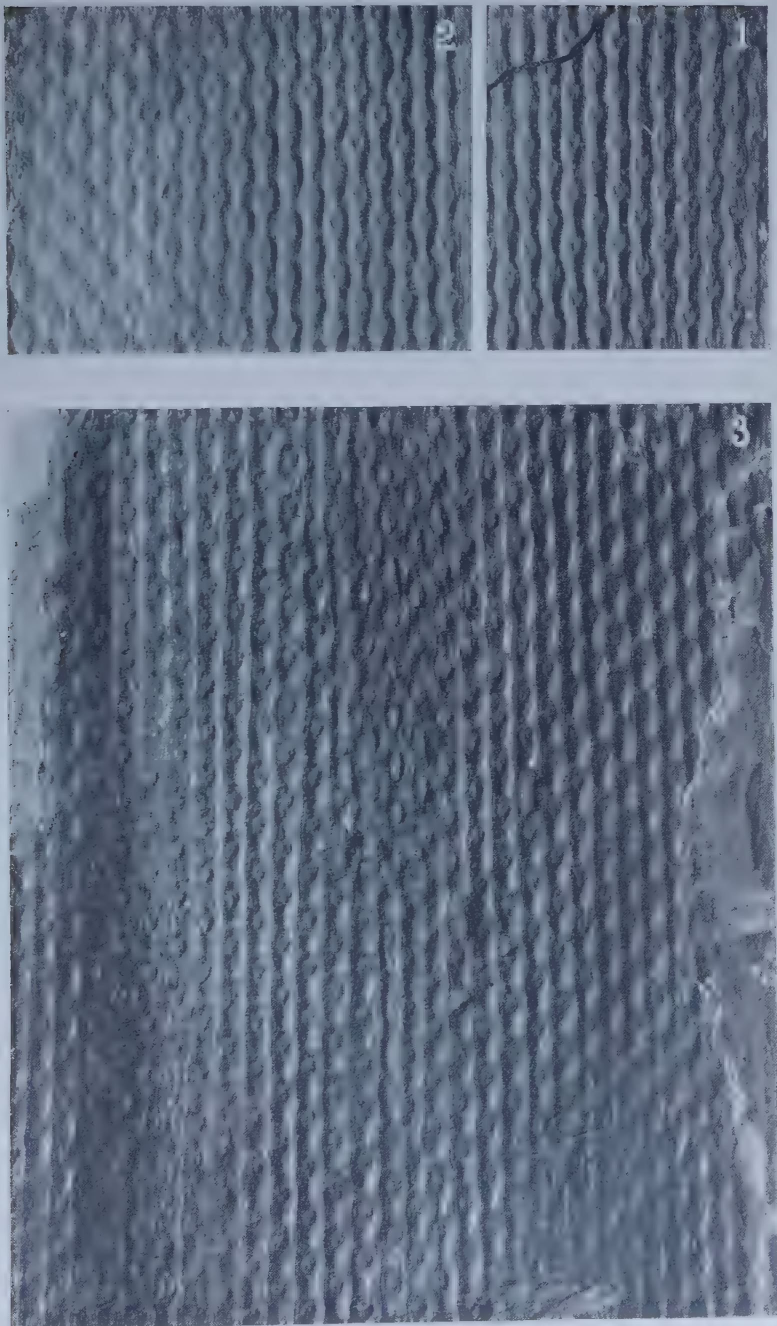


PLATE 8

Natural size; lighted from the left

Fragment of the carbonaceous residue of the flattened tree trunk, from the region shown in part, as an impression, in plate 7, figure 3. The longitudinal costate arrangement of the elongated leaf cushions, bearing the obovate leaf scars, is seen in the middle, while a spiral arrangement becomes more distinct on the right.

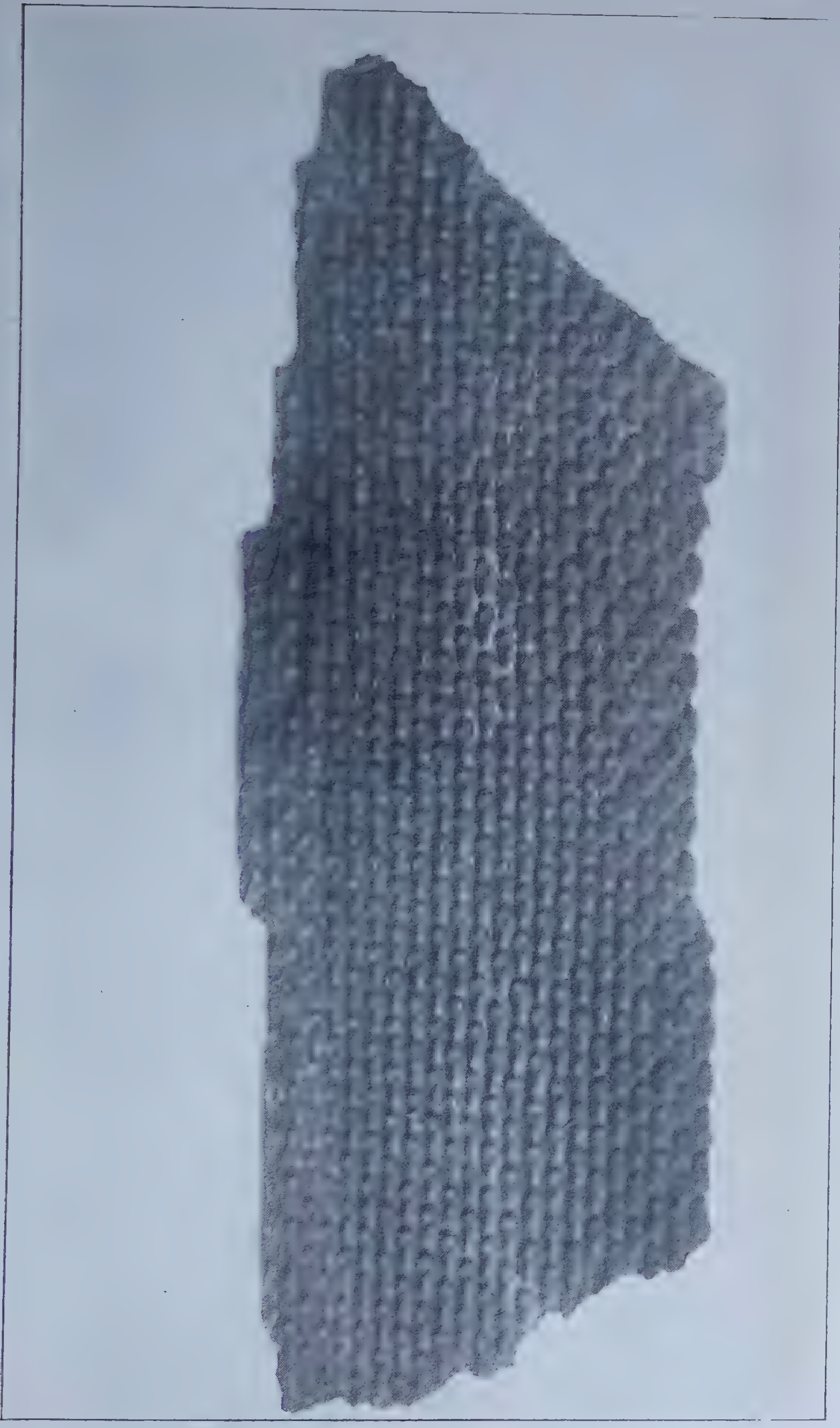


PLATE 9

Figures in natural size; lighted from the right

1 Area from 150 cm above the base, representing that portion of the tree in which the development of the Lepidodendron form of leaf cushion begins to dominate. The sigillarioid ribs along the center are narrowed and exaggerated by lateral pressure. A relatively broad rhomboidal type of cushion is seen on the sides.

2 Cortical impression at 210 cm above the base, at and extending to the left of the center; the median portion of the cortex is very narrowly compressed, the lateral, on the left, showing the lepidodendroid fusiform cushion, in which, as on the right in figure 1, the impression of the leaf bundle sheath is shown through the partially macerated surrounding cushion tissue.

3 Small area near the border of the impression, at about 180 cm above the base, illustrating a short form of lepidodendroid leaf cushion.

4 Small area, at about 130 cm above the base, in which the leaf scars occupy nearly the entire width of the longitudinal ribs.

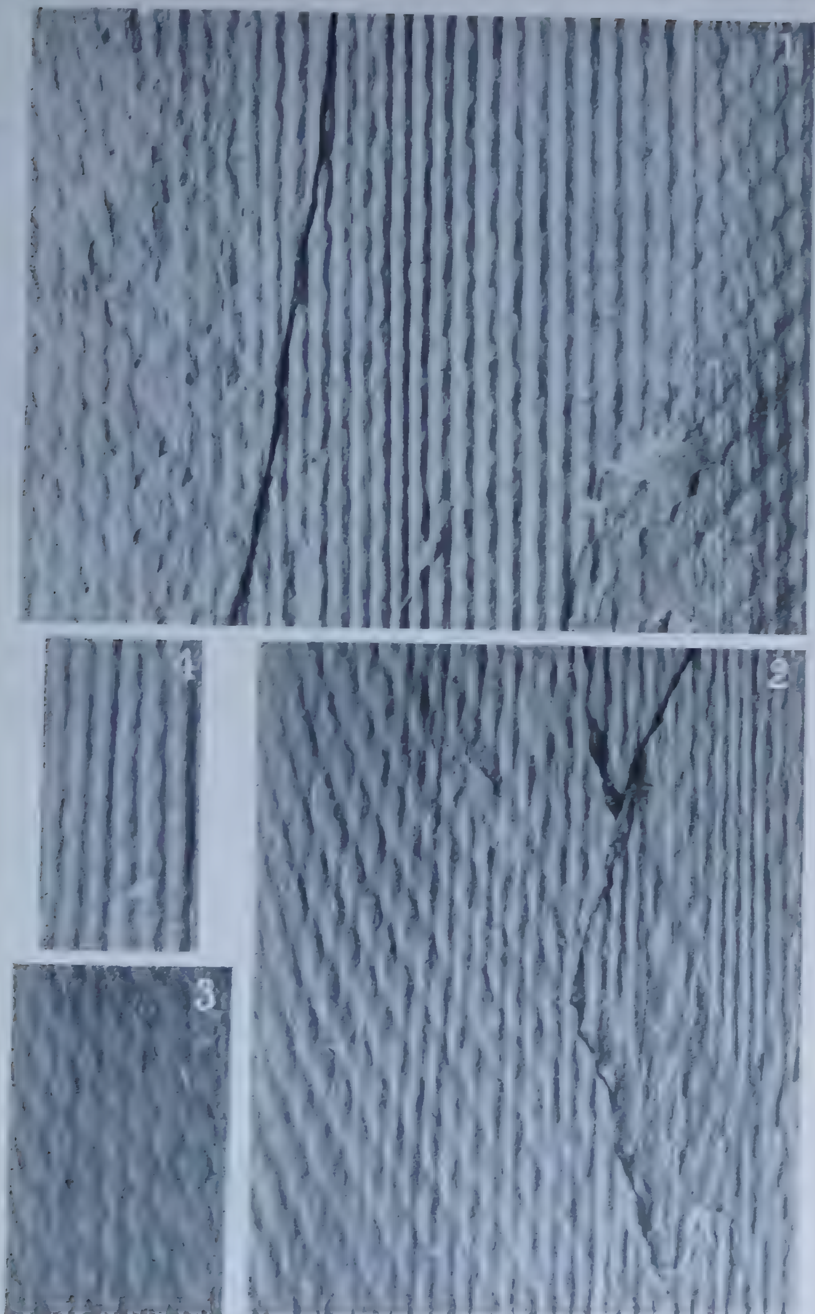

1
4
2
3

PLATE 10

Figures 1–3 natural size; figure 1 lighted from the right, figures 2 and 3, from the left

1 Portion, at 225 cm from the base, in which, on the right, the impression retains partial casts of the leaf trace sheaths passing very obliquely upward and outward, the stage of preservation over a part of the area being that known as Knorria. The costation is narrowed and exaggerated over the median line of the trunk, while in the upper left the cushions present the fusiform (lepidodendroid) type in distinctly spiral arrangement.

2 Cortical impression, at 275 cm from the base, in which the partially macerated tissue permits the expression of the obliquely emergent nerve trace sheaths.

3 Marginal area, at 280 cm from the base, showing the elongated form of lepidodendroid leaf cushion. Along the left border several leaves (L) are seen still attached to the bolsters. Figure 3 is inverted.

4 Slightly enlarged detail of leaf cushion from nearly mid-length of the trunk, showing the obovate leaf scar, the ligular pit just above it, and the nerve trace above the center of the scar.

5 Portion, enlarged, of rib showing leaf cushion, leaf scar and the greatly elongated parichnoian cicatricules which are usually slightly in-hooked at the top and which tend to meet in the lower part of the leaf scar so as to form a horseshoe-shaped cicatricule nearly embracing the nerve trace.

6 Enlarged and semidiagrammatic detail of the leaf still attached to the cushion.


1
4
6
5
2
3
L
T
T

PLATE 11

Natural size; lighted from the left

Segment very near the top of the fossil trunk, which in this region presents exclusively lepidodendroid cushions in distinctly spiral arrangement. In many cases portions of the leaf cushion tissue adhere to the rock. At the left several rather abruptly reflexed leaves (L) may be seen.

STRUCTURAL AND STRATIGRAPHIC FEATURES OF THE BASAL GNEISSES OF THE HIGHLANDS[1]

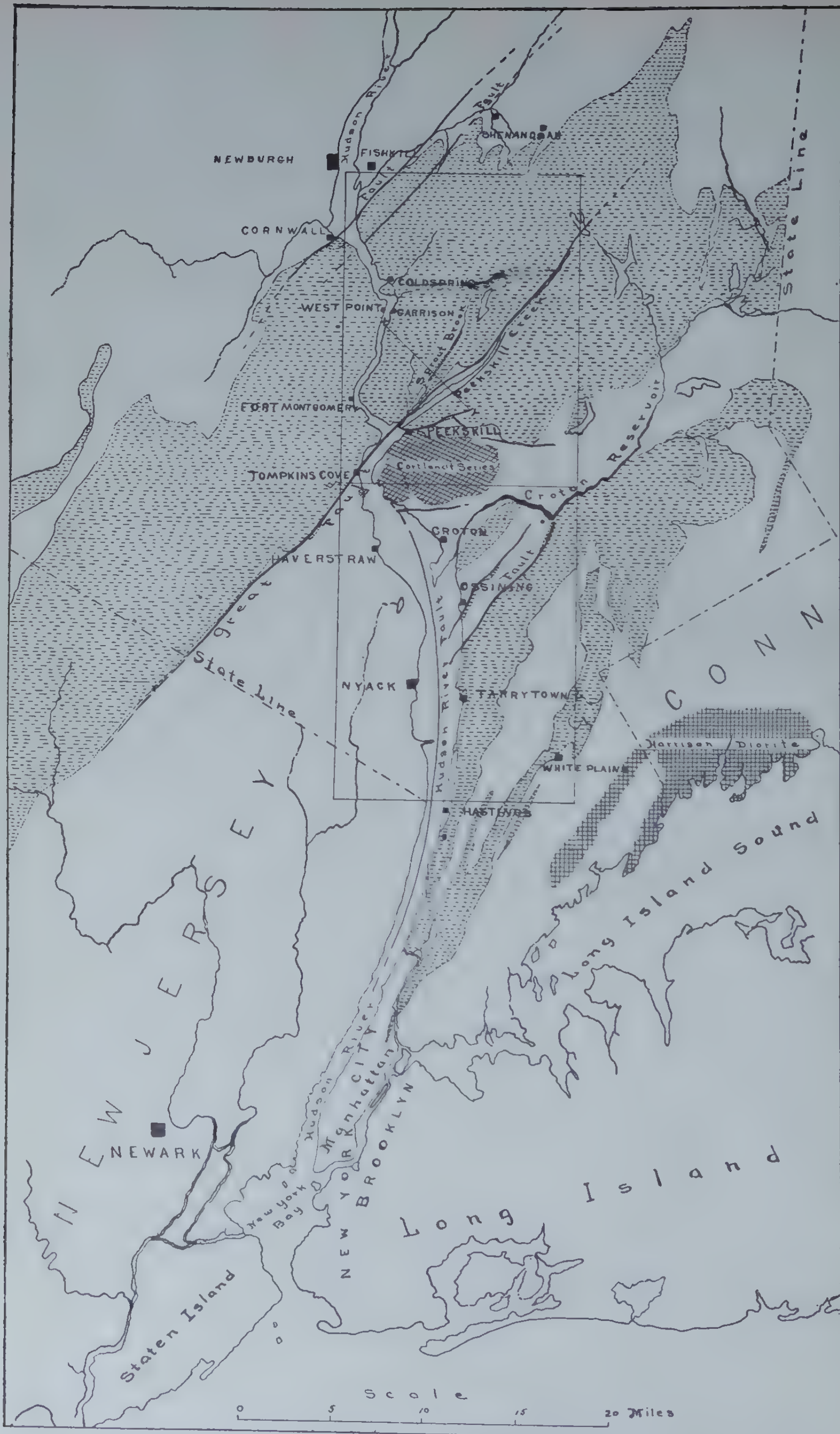
BY

CHARLES P. BERKEY

General statement

The lowest and oldest, as well as the most complex in structure and rock variety, of all the formations of the Highlands region of southeastern New York is essentially a series of gneisses. Geographically they extend in a succession of ridges, separated by belts of limestone and schist, with a northeast-southwest trend on the east side of the Hudson river from New York city to the Highlands proper. These separating belts cease in the vicinity of Peekskill and Tompkins Cove, a distance of 40 miles from New York. From that locality northward the gneisses constitute almost the whole areal geology, to the northern limits of the Highlands, forming a broad elevated and rugged belt about 20 miles wide whose chief structural features trend northeastward in essential conformity with the ridges of the southern district. Toward the west, below Peekskill, the series is abruptly terminated at the Hudson river. The only other outcrops of these ancient rocks occurring on the west side of this line are at the extreme southern part of the district in Jersey City and Staten Island. Above Peekskill in the Highlands proper the same rocks cross the Hudson and continue southwestward into and through northern New Jersey. On the eastern side this formation and its overlying relatives pass into Connecticut.

[1]The observations upon which the present paper is based were made almost wholly in the Tarrytown and West Point quadrangles as outlined by the topographic maps. This work, which consisted of careful mapping in these areas, was supplemented by numerous expeditions into the adjacent Harlem, Ramapo, Skunnemunk, Newburgh and Poughkeepsie quadrangles, and has occupied portions of two summers.



OUTLINE MAP OF SOUTHEASTERN NEW YORK

Adapted from the geological map of New York

Showing position of the Tarrytown and West Point quadrangles and distribution of the larger masses of ancient basal gneisses constituting the Highlands

Petrographic range

No single type of rock can be selected as a constant for this formation. Certain varieties are more abundant than others and thereby give the complex series a certain character that serves to distinguish it from all others of the region. But in isolated outcrops of limited extent an abnormal or unusual type may cause great uncertainty of identification.

Broadly, though, the formation includes banded granitic, hornblendic, micaceous and quartzose gneisses; mica, hornblende, chlorite, quartz and epidote schists; garnetiferous, pyritiferous, graphitic, pyroxenic, tremolitic and magnetic schists and gneisses; crystalline limestone, serpentinous limestones, ophicalcites, serpentine, tremolitic limestone and quartzite; pyrite and magnetite deposits; granite and diorite gneisses; true granite, diorite and gabbro bosses; numerous dikes, stringers and lenses of pegmatite; and occasional basaltic, diabasic, and andesitic dikes. All of these occur with many variations and gradations such as can be seen only in an area of extreme metamorphism and many dynamic disturbances.

Of these the most abundant are the banded hornblendic, micaceous and quartzose gneisses, and the more massive granitic gneisses. The banded type is the most characteristic for the whole region. The most suggestive as to origin and interpretation are the quartzose rocks and the limestones, while the most deceptive and difficult are the granites and granite gneisses. Among these rocks there are numerous representatives of metamorphosed sediments of such character and relationship that their origin can not be mistaken. Almost as abundant are the igneous types, chiefly granites and their metamorphosed derivatives. Frequent small members are found whose origin is uncertain; but in almost every case similar varieties occur under conditions of relationship that usually leave no doubt as to their position and interpretation.

General structural features of the formation

Almost all of the various schists and banded gneisses, together with all of the quartzites, quartzose gneisses, graphitic schists, and limestones form an interbedded series. At all contacts between those members they are conformable. Most of them are thin beds. Several of the limestones are only 3 to 10 feet

thick and the largest yet seen need not be more than 30 feet. The quartzites and quartz schists are similar in their distribution but more common and occasionally more extensive. The banded gneisses and the more massive granitic gneisses are much more heavily developed and their thickness is not known.

The whole series is folded, crumpled, faulted, crushed, injected, intruded and intensely modified by recrystallization; but through it all they retain the fundamental association and essential character of an original sedimentary series. Nowhere is there a basal conglomerate. What is beneath is unknown.

Many of the occurrences of gneisses, a few of the schists, and all of the granites, diorites and gabbros are of igneous origin but all occur as intrusions or injections, as sills, dikes or bosses cutting the metamorphosed sedimentary members of the formation. Except in rare instances they are not even of sufficient constancy or prominence or areal extent or individuality to be given an independent designation. The most notable ones coming within such limitations are the "Yonkers gneiss," which appears to have been a great granite sill that can now be traced along the axis of the southern ridges for a distance of 15 miles; the "Storm King granite," which has a large development in Storm King and Crows Nest mountains and in the Breakneck ridge along the northern border of the Highlands; and the "Cortlandt series" of gabbro-diorite-granite rocks forming an immense boss on the east side of the Hudson river between Peekskill and the Croton valley. Even these, except the "Cortlandt series" are but large, intruded masses wholly within the gneiss formation. At the extreme southeast the "Harrison diorite" in its relations is somewhat similar to the Cortlandt series. Both cut through the gneisses into higher formations.

That this is the true relation between the igneous and sedimentary members is supported by the numerous eruptive contacts and inclusion phenomena. Of these no more convincing evidence need be sought than the occurrence of large angular masses of the banded gneisses and related sedimentary beds of various types wholly included within the granites along such marginal belts as at Constitution island, or on the west side of the Hudson near Fort Montgomery, or at the fresh workings of the Mohegan quarries a few miles east of Peekskill. At Constitution island only the more massive banded gneisses

occur, and therefore the association is somewhat obscure, although the relationship can be seen on the cliffs facing the main channel of the river. Below Fort Montgomery, on the contrary, great angular masses 20 to 50 feet in length, commonly of the quartzose and schist types and even the interbedded limestones themselves are included in the granite in the most strikingly clear-cut way. Nowhere are they better shown than along the cuts of the West Shore Railroad at that place. At the Mohegan quarries, the freshest and youngest and most massive type of granite of the Highland region breaks through not only the gneisses but also the uppermost of the crystalline formations of the district. In the quarry and the adjacent hillside, large inclusions of gneisses, quartzites and schists occur in even more complex development than in the other cases mentioned. Occasionally fragments of the later formations lie in proximity to those of the gneisses, all completely surrounded by true granite matrix.

With the sheetlike intrusions and smaller injections there is much less disturbance of this sort, and the eruptive nature of the contacts is chiefly evident in lenslike enlargements or dikelike development. On a large scale this is best developed with the "Yonkers gneiss," noted before, in the ridge extending from Mount Vernon through Scarsdale and White Plains. Similar relations on a large scale prevail in certain parts of the broad gneiss belt nearest the Hudson river from Spuyten Duyvil to the Croton valley. But in this case the intrusive is less easily distinguished from the inclosing series; it is itself gneissoid, and is more irregular in areal development, small intrusions of similar type are exceedingly numerous, too numerous and too limited in extent to be mapped or indicated separately. The lower limit is represented by the small pegmatite injections of a few feet or rods in length, lenslike bunches and stringers, sometimes making up a considerable portion of the formation, in some places surely connected with larger igneous masses, while in others they may have no true igneous origin. All are essentially but parts of the great basal gneiss, and the line separating those of sufficient prominence to be mapped as distinct members from those neglected or merged in the general color is wholly an arbitrary one.

Members of the basal gneiss

Systematic work from New York city to the northern borders of the Highlands on both sides of the Hudson river, especially in the Tarrytown and West Point quadrangles, reveals no evidence of any fundamental break or change in the gneiss formation. "The Fordham gneiss" of the Harlem quadrangle as indicated in the New York City Folio 83, United States Geological Survey, is not different in position or significance or general character from the same gneiss series of the Tarrytown quadrangle, with which it is continuous; and the writer sees no essential point of difference between these and the basal gneisses of the West Point quadrangle, from which they are separated by only a belt of later limestones and schists occupying the synclinal fold of the lower Croton valley. The same banded types and granitic facies, as well as the same relations to overlying formations, prevail throughout. But in the northern Highlands it appears that interbedded limestones and quartzites and schistose graphitic beds are common, whereas in the southern localities the limestones at least are not so frequently seen. Yet traces of such limestone beds are found as far south as the vicinity of the Jerome Park reservoir in the Harlem quadrangle. Whether they really do occur more frequently can not be determined because of the relative abundance of the overlying formations, which may normally cover the portions that contain these types. The whole area in the north, being eroded down to the gneiss floor, gives much better opportunity to discover the smaller and less resistant members. They are noted at several points and described by W. W. Mather in his *Geology of the First District* published in 1843. The best development of these interbedded limestones is along the Hudson river near Fort Montgomery and Highland Station, and near Garrison at Arden Point, and at McKeel's Corners northeast of Cold Spring. They have all been noted and mapped before, but have not been interpreted in this way.

No subdivision of the gneiss formation at present seems possible. There is no natural stratigraphic break. Because of the abundance and regularity of the igneous injections and the close folding and frequent faulting, it is not even clear as to the order of superposition of the constituent members. At a few places, in what seems to be an upper member, because of its connection with overlying formations, the banded black

and white gneiss most characteristic of the series passes gradually and normally into a mica quartz schist, and this in turn, into a few feet of rather pure quartzite. The best localities are at Sparta, a mile below Ossining; on the Putnam division of the New York Central Railroad, a mile south of Eastview; in the small creek just south of Crugers Station; and on the Harlem division of the New York Central Railroad about a mile north of Chappaqua. At every one of these points, where the relation can be clearly made out, the quartzite is conformable to the banded gneiss. The outcrop at Sparta is by far the most extensive one, but here it is repeated by folding and crumpling to such extent as to make an estimate of thickness very unreliable. It may be more than 100 feet thick there, but it does not reach that amount at any other point. This is the "Lowerre quartzite" named after the locality from which it was first described.

At each of these places, a coarsely crystalline limestone or dolomite, equivalent to the "Inwood limestone" of Manhattan island, lies next above, but not in sufficiently close proximity or sufficiently simple relationship to determine whether or not it is perfectly conformable. Some other considerations [see a later paragraph] indicate that this limestone may not be strictly conformable, although it partakes of practically all of the dynamic modifications that have affected the region. It is suggested that it may be conformable at one group of localities, as is stated in United States Geological Survey Folio 83, and not exhibit the same relation in other parts of the district, indicating overlap conditions. Such apparent conformity is most prominent in the old quarry at Hastings on the northern border of the Harlem quadrangle.

The Lowerre quartzite, therefore, because of its gradational relation with the banded gneisses is, in all essential features, only an upper quartzitic facies of the basal or Fordham gneiss formation. In comparison with the great formations of the area it can scarcely claim a separate classification, but it is a distinguishable bed, the uppermost member, although not separate in any fundamental sense.

It would seem consistent with the characters known for the uppermost members and the succeeding formation (Inwood) to consider the interbedded limestones and quartzites and graphitic schists, as seen along the Hudson river from Fort Montgomery

to Garrison and in the creek valley from Cold Spring to and beyond McKeel Corners, as probably also belonging to the upper members of the gneiss formation. In this case the valley just referred to would represent an eroded syncline and the larger granite intrusions of the mountain ridges on both the northwest and southeast sides would represent eroded anticlines with granitic cores. Although this is a reasonable interpretation no further support to it is at hand, and no subdivision of the gneiss is yet feasible.

Overlying formations[1]

The formations that come in contact with the normal varieties of basal gneiss series are of six apparently separate types. Two are quartzites, two are limestones, and two are schistose to slaty in general character. The two quartzites have definite sedimentary contacts with the gneiss, though not alike. All of the others when in contact have been forced into that relation by faulting. Of the quartzites one is a rather inconstant bed varying from 0 to perhaps over 100 feet in thickness, rarely outcropping and in essential relation closely connected with the basal gneiss. This is the rock described as the "Lowerre quartzite" on a preceding page. The other is a very pure quartzite, of a thickness from 300 to 600 feet, and always with unconformable or faulted contact with the gneiss. It is not believed by the writer that these two formations can be equivalent. If this be granted, the other four formations may be divided into two groups, so that each has a definite and constant relation to one of these quartzites, and this together with allowance for certain structural features, to be described later, makes many of the seemingly abnormal occurrences of rock type in the region intelligible. These six formations are:

5 A phyllite or slate (very thick *"Hudson River"*)

[1] It is recognized by the writer that this is a question of great complexity and considerable difference of opinion and interpretation. There is no attempt in this paper or at the present time to review these opinions or discuss their merits. Likewise it is appreciated that the general question of grouping of these overlying formations affects adjacent districts, with some of which the writer is not familiar.

The reason for discussing local conditions affecting this problem at this time is the more clearly to present the meaning and influence of certain large structures that are not believed to have been given enough prominence and to indicate more fully the true position of the basal gneisses. There is no intention to attempt a broad application of this grouping; but it is believed to be worth while to present the evidence in its favor as it appears in the particular district under discussion.

To W. W. Mather (1) and the late Prof. J. D. Dana (2) and Dr F. J. H. Merrill (3) belongs the chief credit for the descriptions, summaries and interpretations that have been published.

1 Mather, W. W. Geology of New York: Report on First District. 1843.

2 Dana, J. D. Limestone Belts of Westchester County, N. Y. Am. Jour. Sci. XX, 1880.

3 Merrill, F. J. H. Geology of the Crystalline Rocks of Southeastern New York. 50th N.Y. State Mus. Rep't 1896. Appendix A.

4 A fine grained blue and white banded limestone (1000 feet *Wappinger*)

3 A fine grained quartzite (300 to 600 feet, *Poughquag*)

2 A coarsely crystalline mica schist, pegmatitic (very thick *Manhattan*)

1 A coarsely crystalline limestone, tremolitic, micaceous, pegmatitic (200 to 800 feet, *Inwood*)

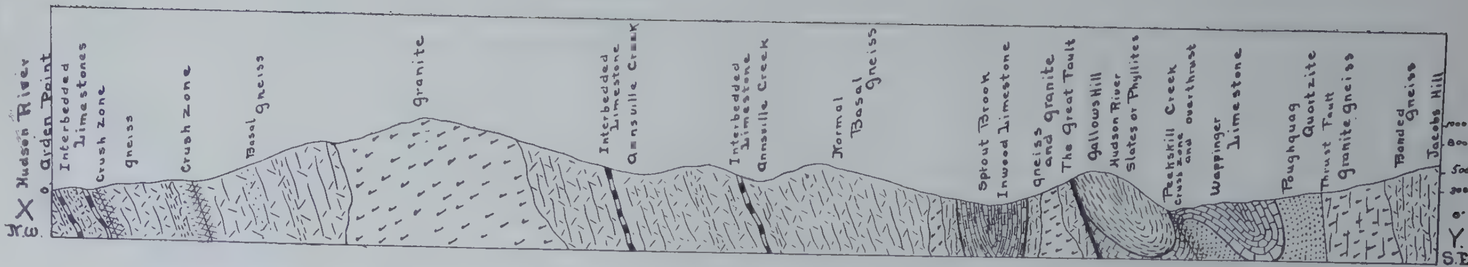
0 A thin schistose quartzite essentially part of the gneiss (1 to 100 feet, *Lowerre*)

Numbers 1 and 2 forming a group, are strictly conformable to each other, and so are nos. 3, 4 and 5. The two groups so far as the writer is aware, are not at any place in direct contact with each other although such relationship may obtain beneath the water level at the mouth of Peekskill creek.

This locality including Peekskill Creek valley and Sprout Brook valley are believed to exhibit features of the greatest significance. From the junction of the two streams about a mile northwest of Peekskill, the two valleys diverge toward the northeast. The lower 3 or 4 miles of each valley carries the formations that are considered by the writer typical of the two groups whose relationships are so obscure. Along the ridge between the two valleys passes a great fault which has allowed the block on the southeast of this line, i. e. the Peekskill Creek valley and adjacent territory, to drop much lower than the northwestern side on which Sprout brook is located. [See discussion of structural features] Therefore, in these two adjacent valleys, formations of very different type occur so near together that their differences must be considered fundamental. In Peekskill Creek valley the typical 3, 4, 5 group occurs—500 feet of quartzite, probably 1000 feet of limestone, and a great thickness of phyllite. This is, without the slightest doubt, the Poughquag quartzite-Wappinger limestone-Hudson River slate group. It is worthy of special note that even on this southern margin of the Highlands these formations have not lost any of their usual characteristics so well exhibited north of the Highlands. The contacts here are fault planes. The whole group is gradually cut out in passing northeastward, the higher beds disappearing first and the quartzite being traceable for at least 10 miles along this valley.

In Sprout Brook valley, only a mile across the ridge, limestone alone occurs. Because of its proximity to the limestone

of Peekskill creek this affords a striking contrast. It is coarsely crystalline whereas the other is fine; it is very impure with silicates and pegmatites, and has occasional dike intrusions and strong epidotic development whereas the other has none; there is no quartzite on either margin of this Sprout Brook limestone and none beneath it, as may be seen by following up the brook to the point where the limestone disappears, whereas the other has at least 500 feet of quartzite conformably beneath. For more than a mile this crystalline limestone occupies the valley for a width of at least ¼ mile. It is well developed for a distance of over 6 miles. It must be several hundred feet thick at the lowest estimate. Farther up the valley, where the limestone disappears, only gneisses of typical Highlands types remain. It is clear that the limestones of these two adjacent valleys can not be the same. The Sprout Brook representative is much the older. It can not by any interpretation be the equivalent of the Wappinger. But the question still remains as to its relationship to other known limestones. Several small interbedded limestones occur in the gneisses at points between this locality and the Hudson river at Garrison. Could this Sprout Brook limestone be an unusually large one of them? Its great thickness, the breadth of valley that it fills for several miles, its final disappearance entirely toward the northeast, and its nonappearance anywhere else in the region are considered insuperable objections to that view. On the other hand if this valley be considered a simple syncline pitching gently southwestward then the limestone becomes an overlying formation of the normal Inwood limestone relationships and character. This is the interpretation of the writer. The syncline is too closely folded and too shallow to have preserved any of the overlying Manhattan schist which it is believed belongs with it. If this is the correct identification then the Inwood limestone and the Manhattan schist are lower and older than the Poughquag quartzite, and therefore can not be correlated with the Wappinger limestone and Hudson River slates as has previously been done.



CROSS-SECTION FROM ARDEN POINT ON THE HUDSON RIVER SOUTHEASTERLY TO JACOBS HILL NEAR PEEKSKILL

Line X-Y on the outline map

Vertical scale magnified two times. Distance six miles

The section presents a generalization of the structural and stratigraphic relations of the most characteristic formations of the region—especially the three types of limestone—i. e. the interbedded limestones of Annsville creek and the vicinity of Arden point, the coarsely crystalline limestone in direct contact with the gneiss at Sprout brook, and the fine grained limestone lying upon 500 feet of quartzite at Peekskill creek.

The intrusive nature of the granites and granite gneisses is indicated. The great Peekskill Valley fault on the line of this section cuts over Gallows hill. It is a normal fault. The others are thrust faults. Several crush zones also are crossed by the section, the principal ones being indicated above. No attempt is made to indicate the very numerous changes in character of the basal gneiss or the frequent occurrence of structures of minor importance.

In general for the whole Highlands region and southward, the lower group, nos. 1 and 2, Inwood and Manhattan, never give evidence of great unconformity with the gneiss. The formations are contorted in an exceedingly complex manner, are always thoroughly recrystallized, follow the general foldings of the lower gneiss and are abundantly injected especially by the pegmatites and basaltic or diabasic intrusions and rarely by granites in similar manner to the gneiss. But the group is not always in contact with the same members of the gneiss series. For example, only a few of the many outcrops of crystalline limestone exhibit a contact with the quartzite referred to as the Lowerre and which it is supposed to succeed. The contacts are quite as likely to be with the banded gneiss or massive granitic gneiss or even granite and schist. Of course, much of this may be due to flowage in connection with the close folding and metamorphism to which the whole series has been subjected. But this common observation together with the fact that the gneiss is much more complexly injected with igneous types and contains an amount of such matter greatly exceeding that found in the overlying group and also types not found in them at all, leads to the conclusion that there is not a perfect conformity with the basal gneiss. It probably represents an overlap type of sedimentary contact.

Number 3, and therefore the whole group 3, 4, 5, is always clearly unconformable on the gneiss where its true relation can be determined. It lies on the upturned and eroded edges of the folds of the basal gneisses. No part of this series is intruded or cut by igneous masses or injected with pegmatites or in any way complicated by the igneous associations so characteristic of the older formations, except by the Cortlandt series. That igneous mass, however, has such a distinct isolation from the other igneous types that it may readily be dealt with as an exception.

This upper group is sometimes not disturbed, as for example along some parts of the northern border of the Highlands, south of Johnsville village and Shenandoah, where the unconformity is beautifully shown and where it may be seen to have taken no part whatever in the metamorphic foldings of the gneiss. This upper group as developed along the northern margin just described is known to be of Cambro-Siluric age. Fossils are not plentiful but have been found at several localities; Cambric

types in the quartzite, both Cambric and Lower Siluric in the limestones and Lower Siluric in the slates. The quartzite is the true "Poughquag."

In Peekskill Creek valley and along the south margin of the Highlands, southwest of Tompkins Cove, the same relations prevail in every respect except that there is later faulting and close folding in this belt. The group, however, is not crumpled and contorted into the complexities prevalent in the lower formations. Only where it comes into contact with the Cortlandt intrusion does it become at all complex in structure or petrographic character.

For these reasons, together with the support given by the fault structure next to be described, but stripped of most of the details of local observational descriptions, it is the writer's opinion that there are two distinct groups of formations above the basal gneisses in the Highlands region. The older and more complex, wholly crystalline, at the base a limestone (Inwood) followed by a schist (Manhattan) both of Precambric age, occupies together with the gneisses almost the whole of the Highlands and the southward extension to New York city. The younger, a Cambro-Siluric series with a thick quartzite always at the base (Poughquag) followed by a limestone (Wappinger) and completed by a slate (Hudson River) forms a continuous border along the north of the Highlands and occurs in only an occasional fault valley along the southern border, notably Peekskill Creek valley, its extension southward, and a few adjacent localities.

Structural features of the region

Folding is evident everywhere. The gneisses almost always stand at very steep angles, vertical or nearly so, and sometimes are overturned, all evidently the eroded edges of large folds. Where proximity to or contact with overlying formations aids in forming a conception of the correct superposition, it appears that the overturning is chiefly toward the northwest.

The general strike of all the major folds is northeast and southwest. But in the vicinity of the Cortlandt igneous mass the strike is nearly east and west. Besides there are occasional cross-foldings on large enough scale to radically change the strike for considerable distances. Minor crumplings indicate a common tendency of this sort. A general cross-folding effect

as one follows the beds northeastward along the strike is an occasional offset of the whole ridge to the northwest. This produces embayments in the gneiss ridges occupied by later formations, such as those along the eastern margin of the principal southern ridge at Eastview and Pleasantville; or it produces pitching anticlines appearing in the areal geology as lenselike outcrops of gneiss, such as that east of Sherman Park or those between Ossining and the Croton valley; or it changes the courses of streams, as at the great bend in the Hudson river from Iona island to Roye hook.

Faults are probably as numerous and complex as the folds, but much more difficult to detect. Estimates of the extent of displacement are valueless except where upper formations are involved in the movements. It is clear, however, that the greater faults follow the general strikes of the folds. Some of the fault zones are so nicely healed by recrystallization that they are not at all apparent by the commoner criteria, and often these zones are not lines of present weakness. But where a limestone formation 500 to 800 feet thick is sheared down to less than 100, or entirely out, as sometimes happens, there is no mistaking the essential fault nature of the displacement. This is characteristic of the older movements. Where the two walls are not so unlike, most of them no doubt escape observation. They occur not only in the valleys but across the higher ridges as well. There would appear to be some cross faulting of this early period also but for this the evidence is not so clear.

A later set of faults is more easily followed. They also are chiefly in line with the northeast and southwest structure, with smaller cross faults, but they have developed prominent shattered zones, slickensides and weaknesses that make detection easier. The displacements noted in the cross faults of this set are not in any case great and their strike does not vary greatly from east and west in the clearest cases.

The principal northeast and southwest faults of this later set, however, occasionally exhibit a great throw. Among them are two that will serve the present purpose and that deserve special attention because of their bearing on other issues. One of these, not in any strict sense a single line, but rather a succession of them, follows closely the northern border of the Highlands ranges, each separate fault line striking out toward the northeast into the bounding slates and its place taken by another

nearer the margin. One of these follows closely the northern base of Storm King mountain and Breakneck ridge. Where it is best exposed, a mile southwest of Cornwall Station, the walls show a fault plane dipping steeply to the southeast with the granites of Storm King overriding the Hudson River slates. This overthrust, therefore, represents a displacement of probably 2000 feet and perhaps more. The overthrust tendency from the southeast is apparent at many other places, and it serves to create some most abnormal relations throughout the Cambro-Siluric area lying to the north where overthrusts of great complication are the rule, such as that at New Hamburg or at Cronomer hill, north of Newburgh.

The other notable fault of even greater significance occurs on the south side of the Highlands proper and the escarpment along this line marks a physiographic and stratigraphic boundary for many miles. This fault line follows the west side of Peekskill creek to the Hudson river, crosses to Tompkins Cove, and then passes to the southwestward across the New York State boundary into New Jersey. It sharply limits the Highlands Precambric and its displacement established an escarpment against which the Triassic sediments were laid down and which yet marks their interior limits. Present conditions of the strata preserved along this line indicate two separate movements: first, block faulting and tilting by which the south wall was dropped probably 2000 feet or more, carrying down into the trough thus formed all the overlying Cambro-Siluric formations that at that time covered the Highlands; later a thrust from southeast closely folding the sediments entrapped in this trough and in places thrusting the gneisses upon them. The net result is a preservation of representatives of the later group of formations (Cambro-Siluric) along this fault line. This is especially successful on the margin of the down faulted block, so that, in Peekskill Creek valley and the next small valley to the southeast, and from Tompkins Cove southwestward for some distance, these formations may be seen. But because of the somewhat similar succession of members and character, and because of the oversight of this profound structural break, the identification of the formations of this district has been confused with the older group. It is the writer's belief that this allowance made for the occurrence of the seemingly abnormal strata in the southern Highlands permits reasonable explanations for all occurrences

and is a considerable support for the theory of two separate sedimentary groups. These larger faults are believed to be chiefly responsible for the sudden disappearance of the Manhattan schist.

If there be, as seems reasonable, a north and south fault in the Hudson river also from Peekskill southward, it will be noted that such a line would intersect the one just described in the Peekskill area. Most suggestive is the occurrence of the Cortlandt igneous intrusion just at the acute angle of the depressed block thus outlined. On every margin of the Cortlandt area are evidences of faulting, fault breccias, shear zones, clear-cut faults, great inclusions, and abrupt transitions. That this igneous outbreak is genetically connected with the development of excessive weakness at this point by the block and thrust faulting of the district appears to give an explanation of its limited areal distribution and its occurrence at a time not marked by igneous activity in other unrelated areas.

Age of the basal gneisses

The age and exact correlation of this lowest formation is unknown. It has all the physical character of the "Grenville series" of the Adirondacks and Canada as described by geologists in those districts and as seen by the writer at a few points in the Adirondacks. In view of the agreement in petrographic character and general stratigraphic features it is believed to be a part of the "Grenville series." It is surely not Archean, in the present meaning of that term as now applied in the Great Lakes region of the United States and Canada.

The relative age of this formation is more clear. It is the oldest of the immediate region under discussion. It is wholly Precambric. It is, in the writer's opinion, separated from the lowest representatives of the Cambric shown above by one overlap unconformity probably of no very great time break, a group of sediments (Inwood limestone and Manhattan schist) of great thickness, and an unconformity marked by mountain folding and erosion. Therefore it is immensely older than the Cambric and its stratigraphic position under this conception of the relations between the overlying formations may be tabulated as follows:

Tabulation of the formations

	SEDIMENTARY SERIES	IGNEOUS SERIES
	Unconformity	Cortlandt series
Lower Siluric	Hudson River slates	Diorites Gabbros Peekskill granite
	Wappinger limestone	
Cambric	Poughquag quartzite	Harrison diorite
Precambric	Unconformity	Pegmatites
	Manhattan schist	Basaltic and diabasic or dioritic intrusions
	Inwood limestone	Granite and other dikes
	Overlap unconformity	
	Grenville series Lowerre quartzite, Fordham gneiss, and the various basal gneisses of the Highlands, including interbedded limestones, quartzitic and graphitic schists	Storm King granite Yonkers gneiss and other granites, diorites, and corresponding gneisses

Relative age of the igneous intrusions

All igneous rocks of this area are younger than the sedimentary members of the basal gneiss. But there are great differences among them. Some of the intruded stringers and sills may date back to the early history of these sediments since they partake of all the metamorphic changes that characterize these ancient strata including recrystallization and flowage. Representatives of such early types are mostly granite gneisses and are everywhere confined to the basal gneiss formation. Many of them are very similar to the coarser metamorphosed sediments and lead to the greatest uncertainties of interpretation. Others, such as the pegmatite streaks and some of the basic intrusions of original diabasic character, belong to the period of most extensive metamorphic activity and penetrate also the next overlying limestone (Inwood) and the schist (Manhattan). But they do not affect anything higher. Therefore

they are of later age than the gneiss proper, although still Precambric according to the writer's interpretation of the series. The Harrison diorite appears to belong to this general position or perhaps still later. Last of all is the Cortlandt series of gabbros and diorites cutting every formation in the district and including fragments of them so that this last must be Post-Lower Siluric in age.

INDEX

Page numbers referring to descriptions of fossils are printed in black-face type.

Published monthly by the

New York State Education Department

BULLETIN 408 JULY 1907

New York State Museum

JOHN M. CLARKE, Director

Bulletin 111

GEOLOGY 13

DRUMLINS OF CENTRAL WESTERN NEW YORK

BY

H. L. FAIRCHILD

New York State Education Department

Science Division, October 19, 1906

Hon. Andrew S. Draper LL.D.

Commissioner of Education

SIR: I communicate herewith, for publication as a bulletin of the State Museum, an important paper on the glacial phenomena of New York, entitled the *Drumlins of Central Western New York* by Professor H. L. Fairchild.

Very respectfully yours

JOHN M. CLARKE

Director and State Geologist

Approved for publication October 20, 1906

A. S. Draper

Commissioner of Education


MAP SHOWING
GENERAL DISTRIBUTION OF DRUMLINS IN
CENTRAL-WESTERN NEW YORK
H. L. FAIRCHILD
1905
Scale:
1 inch=12 miles
LAKE ONTARIO
247
LAKE ERIE
573
ONEIDA LAKE
370
Toronto
Hamilton
Whitby
Port Hope
Kingston
St. Catherine
Port Colborne
BUFFALO
Rochester
Syracuse
Watertown
Sacket Harbor
Cape Vincent
Clayton
Alexandria Bay
Oswego
Fulton
Lewiston
Niagara Falls
Lockport
Medina
Albion
Brockport
Charlotte
Tonawanda
Akron
Batavia
Attica
East Aurora
Hamburg
Warsaw
Geneseo
Mount Morris
Canandaigua
Geneva
Waterloo
Seneca Falls
Auburn
Honeoye Falls
Penn Yan
Ovid
Naples
Dansville
Portage
Ithaca
Trumansburg
Watkins
Moravia
Groton
Cortland
Tully
Bath
Hornellsville
Canisteo
Alfred
Belmont
Wellsville
Olean
Addison
Corning
Franklinville
Sandusky
Springville
Dunkirk
Fredonia
Mayville
Jamestown
Little Valley
Chautauqua Lake
Cattaraugus Cr.
Tonawanda Cr.
Allegany R.
Salmon R.
Tioughnioga R.
Otselic R.
Chenango
SENECA LAKE
CAYUGA LAKE
N I A G A R A
O R L E A N S
M O N R O E
G E N E S E E
E R I E
W Y O M I N G
L I V I N G S T O N
O N T A R I O
Y A T E S
S E N E C A
C A Y U G A
O N O N D A G A
O S W E G O
J E F F E R S O N
C O R T L A N D
T O M P K I N S
S C H U Y L E R
S T E U B E N
A L L E G A N Y
C A T T A R A U G U S
C H A U T A U Q U A
80°
79°
78°
77°
76°
42°
43°
44°

New York State Education Department

New York State Museum

John M. Clarke, Director

Bulletin 111

GEOLOGY 13

DRUMLINS OF CENTRAL WESTERN NEW YORK

BY

H. L. FAIRCHILD

Introduction: general description

Among the varied products of glacial work the smooth mounds and ridges known as drumlins are the most singular. They are the product of continental glaciers by the unique rubbing or molding action of the latter as plastic solids. In their form, attitude, composition and relation they are not only the most remarkable and interesting of the glacial drift deposits but in their graceful outlines and smooth surfaces they are the most striking and beautiful of drift forms, if not of all topographic forms of moderate size. Long before the glacial origin of the drift was established these smooth-outlined hills had attracted attention. They were cited as an objection to the theory of continental glaciation because they seemed inconsistent with the supposed planing and leveling effect of the ice sheet; and even up to the present time they have remained something of a difficulty if not a puzzle. Although the subglacial origin of the drumlins is generally admitted and their constructional genesis conceded, at least in part, the precise mechanical operation in their upbuilding by the antagonistic and balancing forces has not been analyzed. Some of the factors in this complicated problem in glacial mechanics will be indicated below.

The State of New York may claim with confidence the possession of the most remarkable group of drumlins in the world, when all the facts relating to them are taken into account. This drumlin area has been under the writer's observation for several years and the results of the study will help, it is thought, to elucidate the

problem of drumlin formation. It is recognized that no single drumlin area may exemplify all the features belonging to these drift forms, but the New York area includes such a large variety of forms and relationships that it should illustrate the fundamental mechanics and most of the phenomena.

For the reader who may not be familiar with this form of the glacial drift a brief description of its general character will be appropriate. That these hills are of glacial origin is evident from their location always within the glaciated territory, their superficial position and their composition which is compact till or ground moraine, at least in New York. Their molded forms show the overriding effect of the ice and they are believed to have been shaped, if not constructed, under the relatively thin and weaker border of the continental ice sheet, along the zone where the ice in its transporting power became incompetent to carry further its drift burden. Their forms vary from mounds to long, slender ridges; and their size from massive, conspicuous hills, 100 or 200 feet high, to indefinite swells of the drift surface.

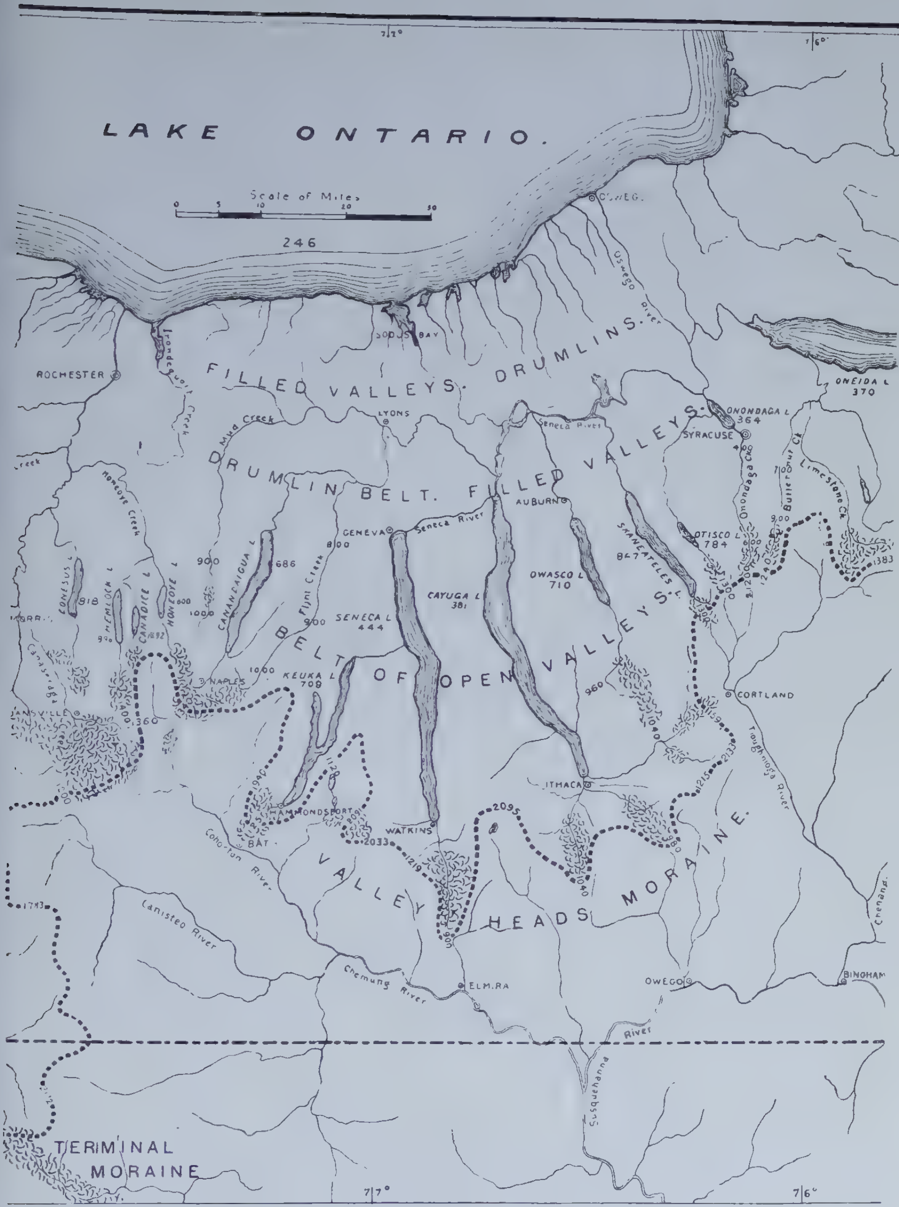
The history of the earlier study of drumlins may be read in the article by W. M. Davis, "Distribution and Origin of Drumlins" [*see* p. 437]; and also in the papers by Warren Upham, specially those of the years 1889, 1892 and 1893 [*see* p. 438]. A brief synopsis of the description by Kinahan and Close of the type drumlins in Ireland is appended as pages 435–36, with a copy of part of their map [pl. 47].

The following names were formerly applied to the drumlin forms: parallel ridges, Sir James Hall, 1815; drumlins, H. M. Close, 1866; parallel ridges, Shaler, 1870; lenticular hills, Hitchcock, 1876; whalebacks, Matthew, 1877; drums and sowbacks, J. Geikie, 1877; parallel drift hills, Johnson, 1882; mammillary and elliptical hills, Chamberlin, 1883.

The name "drumlin" (derived from the Celtic and meaning "little hill") was first applied by H. M. Close in 1866 to these drift hills in Ireland. The various names formerly applied have by common consent given way to the present name, which was introduced in this country by W. M. Davis in 1884

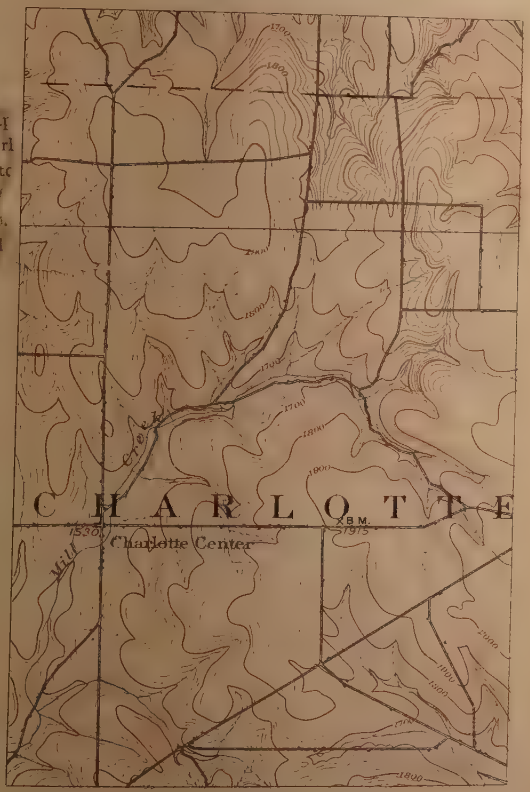
Drumlins are so diverse in their form, and possibly in their precise origin, that any terse definition must be somewhat vague. The smooth form, convex profile and parallelism with the ice flow

Plate 2



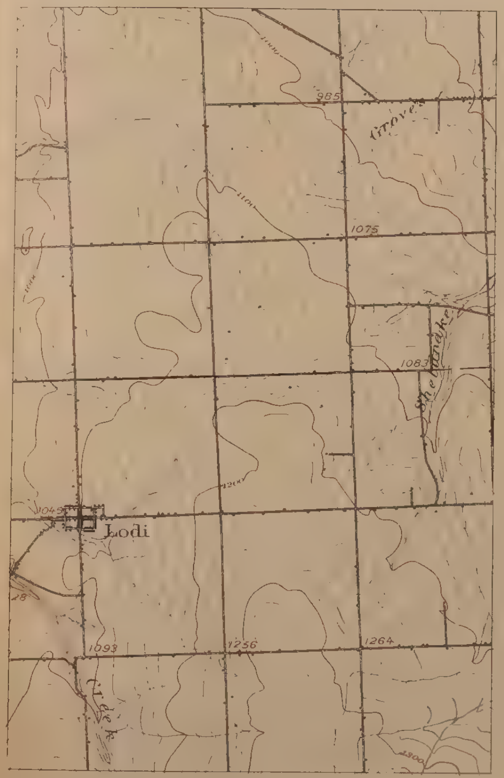
PHYSIOGRAPHIC BELTS IN CENTRAL NEW YORK

PART OF CHERRY CREEK QUADRANGLE



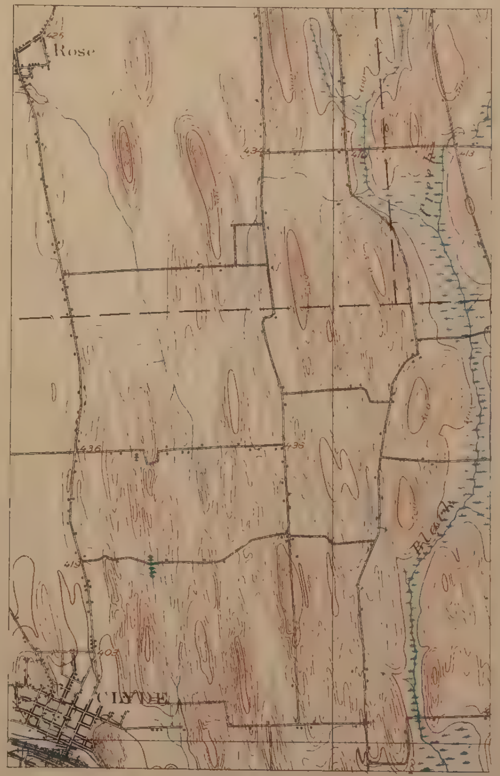
1. Rock forms; non-glacial.

PART OF OVID QUADRANGLE



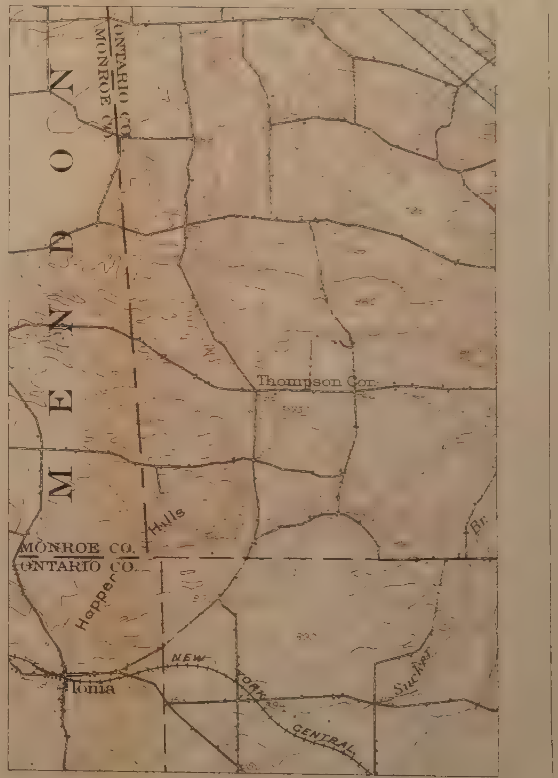
2. Till-covered slopes; expressionless.

PART OF CLYDE QUADRANGLE



3. Drumlins.

PART OF CANANDAIGUA QUADRANGLE



4. Moraine

TYPES OF NEW YORK TOPOGRAPHY

H. L. Fairchild 1905

direction are the striking superficial characters; but along with these elements the composition and subglacial origin must be recognized. Omitting reference to the precise manner of their amassing, they may be defined as smooth-surfaced hills of till, elongated in the direction of ice movement by the rubbing action of the ice sheet. Or, more briefly, they may be defined as smooth drift hills shaped by ice molding.

The topographic expression of drumlins is so emphatic that any group with fairly developed forms is readily distinguished on maps in 20 foot contours. Plate 3 affords a comparison of drumlinized drift with other forms of glaciated topography.

It appears that the molding effect of the overriding ice was not restricted to the drift masses deposited during the rubbing process by the ice itself, but was felt by moraines or even by rock masses which were exposed to the ice rubbing. The latter effect is seen specially along the summits of the rock ridges that were buried under the glacier [*see* pl. 10]. The name drumlin can not appropriately be applied to ice-shaped rock masses, though the relationship to drumlins may be evident. The term "drumloid" is fully appropriate but the word has long been used in a rather loose and indefinite way for hills of drift having merely a formal and perhaps accidental resemblance to drumlins. A distinctive term with obvious meaning is desirable, and it is proposed to call these forms *Rocdrumlins*, using as a prefix the Celtic word for rock. In the case of ice-worn hills or summits of rock which suggest the drumlin form but do not fully attain it we may use the term *rocdrumloid.*

It should be emphasized that rocdrumlins are an effect of a moderate amount of erosion, or the removal of material, while the drumlins are a product of upbuilding and shaping at the same time [*see* p. 432] The genetic distinction is important.

It seems probable that hill summits of rock should receive under favorable conditions a drumloid expression, that is, a roches moutonné form on a large scale. Plate 16 shows quite as good an example as the published topographic sheets of western New York supply, and even this is somewhat equivocal. Eastern New York can probably furnish better examples. However, it may be said that the erosional work of the continental ice sheet was commonly insufficient, at least in western New York, to strongly mold the hilltops. The absence of such effect is seen in plate 3, figure 1.

Areal distribution

Drumlins have an irregular and apparently capricious distribution over the glaciated territory of Europe and America and over large areas seem to be entirely wanting. None have been reported from Ohio, Indiana, Illinois, Minnesota, the Dakotas, southern Michigan and most of Iowa. They are at least very rare in Pennsylvania and New Jersey. In Maine they are not infrequent but are inferior in numbers and size to those found southwestward.

There seem to be three regions of great drumlin development in the United States. The New England area includes southern New Hampshire, where Upham has mapped nearly 700 drumlins; Massachusetts with 1800, as described by Barton; and a southward extension of the area across Connecticut. The Michigan area includes the eastern part of Wisconsin and adjacent territory in Michigan, where Chamberlin estimates that there are 5000 drumlins; also east of the north end of Lake Michigan in the Grand Traverse district. The third area is the subject of this paper.

Drumlins have been noted in the southern part of Canada by G. F. Matthew, in Manitoba and Athabasca by J. B. Tyrrell, and are said to occur in Nova Scotia.

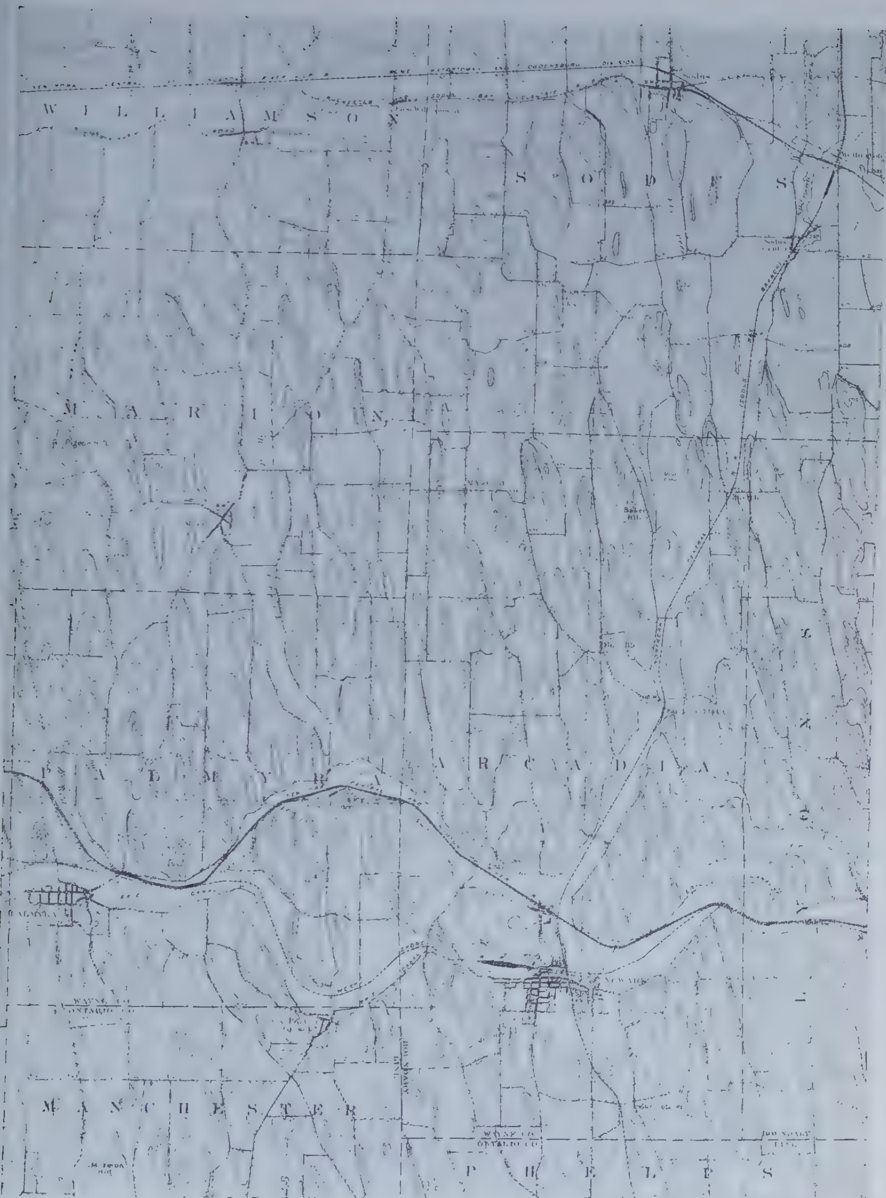
The drumlins of Ireland are the type forms and are briefly described at the close of this paper [p. 435–36]. Drumlins also occur in the Clyde valley in Scotland, and in the Lake Country of England as described by Upham [titles for 1898, p. 439]. In the low grounds of Switzerland they are said to occur; also in northern Germany on the island of Rügen and east of the lower part of the river Oder. Dr Keilhack has described in the latter area a group of 3000 drumlins.[1] They are said to be disposed radially, facing a looped marginal moraine, covering a belt 6 by 20 to 40 miles.

In Scandinavia drumlins have escaped notice, unless certain clay ridges in Sweden, noted by James Geikie,[2] represent drumlinized surface.

When it is recognized that typical drumlin or drumlin ridges are only the most emphatic of a variety of forms produced by the rubbing of ground-contact ice under thrust motion [*see* p. 429], and that on the one hand these forms shade off into indefinite flutings or

1 Keilhack, K. Jahrbuch K. Preuss. geol. Landesanstalt. 1896. p. 163–88.
2 Earth Sculpture. 1898. p. 234.

Plate 4

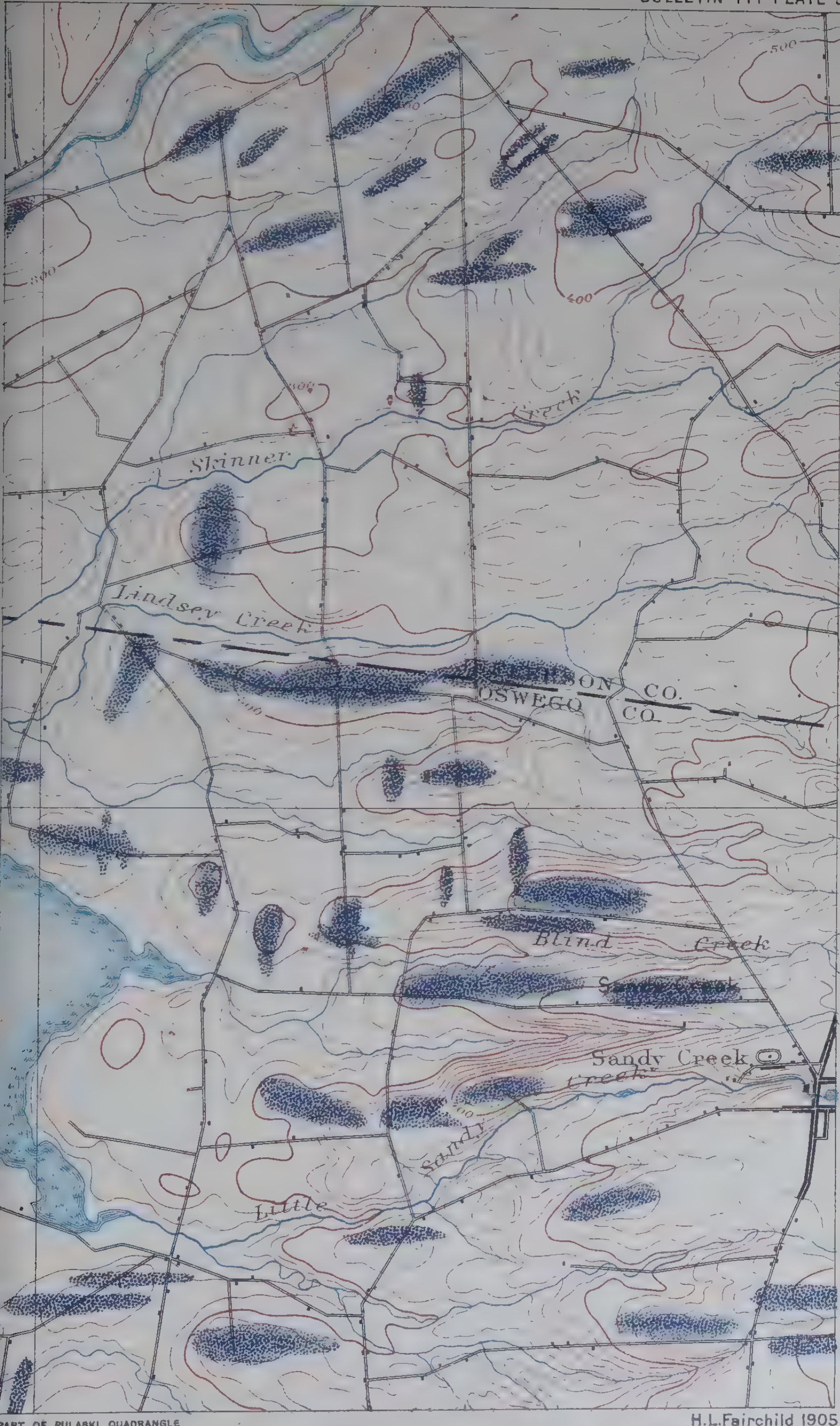


Palmyra quadrangle. Drumlins on the Sodus-Newark meridian. The south edge of the belt lies on the Phelps quadrangle.

EDUCATION DEPARTMENT
JOHN M. CLARKE
STATE GEOLOGIST

UNIVERSITY OF THE STATE OF NEW YORK
STATE MUSEUM

BULLETIN 111 PLATE 5



DRUMLINS NORTHWEST OF PULASKI

Showing the varied directions. Only the more prominent forms are indicated.

moldings of the drift, and on the other hand are represented by scoured or rounded roche-moutonnéed rock hills (rocdrumlins), it is probable that this class of phenomena will be found somewhat more widely distributed in the glacial areas than has been supposed. However, the requisite conditions for production of typical drumlins do not seem to have been commonly fulfilled, as vast areas of the glaciated territory seem never to have been subjected to the drumlinizing movement of the ground-contact ice.

The land surface included in the great drumlin area of New York is a belt about 35 miles wide, bordering the south side of Lake Ontario, and about 140 miles long (from Niagara river to Syracuse), with a total area of about 5000 square miles. At least half of this area, or 2500 square miles, carries numerous and well developed drumlins. The eastward extension of the drumlin area swings around the east end of Lake Ontario as a belt 5 to 10 miles wide, reaching past Watertown into the St Lawrence valley. An area in Chautauqua county can not be estimated as the region is not topographically mapped, but the drumlins are scattering.

The New York drumlin area probably includes not less than 10,000 drumlin crests, of which on a conservative estimate at least 6000 are indicated on the topographic sheets. In the districts where the drumlins are close set from 20 to 35 can be counted in a square of 4 square miles. Five drumlins to the square mile is common. Three to the mile can not be more than the average, counting large and small, and on the 2500 square miles of well developed drumlin topography this would give 7500 drumlins. Estimates have been made by counting the separate drumlin summits or crests indicated by the contour lines in certain limited districts and using the figures for larger areas, with a result giving about 5000 crests for the 15 topographic sheets that cover the best parts of the drumlin area. On the 216 square miles of the Palmyra quadrangle [pl. 4] the estimated number of drumlin crests was 800, while an actual count gave 955. Hundreds of minor ridges are beneath the recognition of the contour lines.

The area of well developed drumlins extends eastward around the east end of Lake Ontario, where they are specially interesting on account of their attitude and peculiar form [pl. 5], and reaches westward as far as the meridian of Batavia. The Pulaski, Sacketts Harbor and Watertown sheets show the northeastward ending of

the Ontario drumlin area, while the lower half of the Brockport, Albion and Medina sheets show the westward termination as far as the drumlin forms are indicated by the map contours [pl. 17]. West of the Genesee river and near the Ontario shore distinct drumlins occur, shown in plate 18, where the Iroquois waters were too deep for effective erosion. Westward, on the Niagara-Genesee prairie, the drumlin forms gradually become very elongated and indefinite low ridges, which slowly change to faint, invisible swells dying out farther west. On the sheets toward Niagara the drumlinized character of the surface is suggested only by the obliqueness of the streams and contours to the general slope [pl. 19].

Southeastward the drumlin area terminates in peculiar fashion, forming a decided point at Syracuse. The most easterly drumlins are the conspicuous group southeast of the city of Syracuse, which stand on a base of Salina shales. The map shows no well formed drumlins north of Syracuse, over the Oneida lake depression, nor on the high ground south of the Syracuse district. This extension of strong drumlins as a tongue or point into a district otherwise destitute of such forms is a striking and important fact.

East of Syracuse, as at Fayetteville, Canastota and Oneida, the soft Salina shales which compose the irregular ground surface show no effect of ice rubbing and carry only just enough drift to prove the former presence of the ice sheet. The topography is easily mistaken for morainal, but is due to atmospheric erosion.

Plates 5 to 21 show some groups of drumlins, interesting for either attitude or form, arranged somewhat in geographic order from east to west. The Weedsport [pl. 11], Clyde and Palmyra [pl. 4] sheets show the best display of drumlins, though other sheets exhibit numerous and interesting forms.

In the zones of wave erosion by the glacial lakes the drumlins were cut or entirely removed. Lakes Warren and Dana were too short-lived in the Ontario basin to do more destructive work than cutting notches in the drumlins and building the debris into adjoining gravel spits and bars [pl. 17]. The same applies to Lake Iroquois in its great Cayuga-Syracuse embayment, reaching from Sodus to Richland. But along the continuous or maturer shore of Iroquois, extending from Niagara river to Sodus and from Richland to Watertown, as well as along the living shore of Ontario, no drumlin has been able to stand up alone against the waves;

UNIVERSITY OF THE STATE OF NEW YORK

STATE MUSEUM

PART OF FULTON QUADRANGLE. H.L.Fairchild 1905

LONG-RIDGE DRUMLINS AND OVERLAPPING MORAINE

Moraine overlaps and replaces the drumlins on the north. Only the north border of the drumlin area is shaded

PART OF SODUS BAY QUADRANGLE.

DISSECTION OF DRUMLINS BY ONTARIO WAVES

H.L.Fairchild 1905

although they survived where immersed in more than 30 or 40 feet of water.

At Sodus village the Iroquois beach, the "Ridge road," is an erosion cliff in several strong drumlins. Westward the north border of the Syracuse-Rochester drumlin area swings to the south of the beach and follows about west-southwest to the Genesee river, and thence west and north of west to the limits of the area northwest of Batavia. The following places in order westward lie at the northern limit of abundant drumlins: Sodus, Williamson, Lincoln, Penfield, Pittsford, Churchville, Bergen, Oak Orchard Swamp.

Eastward from Sodus the Iroquois shore with less maturity curves southward around Sodus bay, but still marks a north limit of the close set drumlins. The villages along this border are: South Sodus, Wayne Center, Rose, West Butler, the line passing 2 miles southeast of Wolcott. The northern border of the Syracuse-Rochester area curves so as to lie approximately at right angles to the axial direction of the drumlins.

South and east from Sodus bay, over the Montezuma and Oneida lowlands, the groups of drumlins stood as islands in the Iroquois waters.

East and northeast from Sodus bay a somewhat distinct area of heavy drumlins borders the shore of Ontario; and it is this series which passes around the east end of the lake toward Watertown. The villages of Fairhaven, Fulton, Mexico and Pulaski lie in this area.

Passing lakeward from the Iroquois beach, into what had been deep waters, a belt of drift forms, moraine or drumlins, gradually appears which is abruptly terminated by the present Ontario beach. It would be interesting to know if the waters of Ontario hide drumlins in their depths. As a series of heavy drumlins are opposing the waves all the way from Sodus to Oswego [pl. 7, 8], it seems quite certain that northern members of the group have escaped destruction by submersion in the deeper waters.

The southern limits of the great drumlin area are even less definite than the northern and can not be tersely stated. Approximately they may be given as follows: The western extremity of the area is bounded on the south by the shore of the ancient Lake Warren from Indian Falls to Leroy. From Leroy the drumlins spread south up the west slope of the Genesee valley to Mount

Morris, and extend westward on the high ground (1200 to 1800 feet) past Pavilion, Wyoming, Dale and Linden to Attica. East of the Genesee river the southern limit may be taken as a line joining the south end of Conesus lake with the north ends of Hemlock and Honeoye lakes, the middle of Canandaigua lake and the north ends of Seneca, Cayuga, Owasco and Skaneateles lakes; and thence eastward south of Syracuse to Fayetteville. The villages and cities which nearly mark this boundary are Oakfield, Leroy, then the southwestward stretch to Attica and Mount Morris, Conesus, Hemlock, Honeoye, Middlesex, Potter, Geneva, Waterloo, Seneca Falls, Cayuga, Auburn, Skaneateles, Marcellus, Onondaga Hill, Jamesville and Fayetteville.

In a broad way it may be said that the general area of drumlins covers all the low ground of the Ontario plain north of the Finger lakes and reaches up the north-facing slope to high ground approaching the divide. Between Honeoye and Canandaigua lakes the drumlins lie as high as 1700 feet.

Within the great drumlin area as described above some minor divisions can be recognized With reference both to time and to southern position the first series or group may be designated as the Attica-Geneva series or the western Finger lakes series. This lies on the higher ground and includes the area between the Tonawanda valley and Seneca lake, covering the section of the Genesee valley, and Conesus and Canandaigua lakes as noted above.

The second series, Oakfield-Palmyra-Syracuse, lies on the low ground and includes the central part of the drumlin district and the most striking drumlin topography, with a width in the central part of about 20 miles. On the meridian of Rochester, east of the Genesee river the first and second series are united.

A third and still later series includes the drumlins which border Lake Ontario from Sodus eastward — the eastern Ontario series.

The drumlinizing of the Niagara-Genesee prairie (subsequently the Iroquois lake bottom) was probably contemporary with the second and main series. The complete mapping of the somewhat indefinite morainic belts, a study now in progress, will determine more certainly the time relations of the several drumlin series. Plate 1 shows the distribution as well as it can be portrayed at present.

A separate group of drumlins lies on the high ground about

W YORK

ITARIO WAV

Chautauqua lake, with direction pointing southeast [pl. 21]. Another group occurs about the north end of Cazenovia lake, with altitude up to 1400 feet. Scattering drumlins occur in many localities, and probably at even higher altitudes than noted above.

The amount of land surface included in the principal drumlin area is roughly estimated as 2500 square miles without including the portion east of Lake Ontario.

Some of the peculiarities of the main drumlin series, the Oakfield-Syracuse, in the matter of definite boundaries and minor grouping should be noted here. These features, though difficult of verbal description, appear very striking on a large map made by joining the topographic sheets. Along the northern border of this series from Sodus east to Irondequoit depression the drumlins are quite abruptly replaced by morainic topography [pl. 15], the relationship being discussed later [p. 424]. The north border of the eastern Ontario series shows the change from drumlins to moraine even more plainly [pl. 6].

On the southern borders the drumlin topography sometimes shades off into smooth drift [pl. 13], while in other districts it is lost in the bolder relief of the rock hills [pl. 16].

The most abrupt ending of the drumlin topography is along the courses of ancient glacial river drainage. A series of drainage channels marks the definite southern limit of the second drumlin series from Victor to Geneva, and on the west of the Genesee at Leroy and Mumford. A later drainage course, from Fairport to Syracuse, traverses the heart of the drumlin series, and seems responsible for the isolation of minor groups, the peculiar forms of which are indicated in plates 9 to 12.

Orientation

The attitude of the drumlins with reference to compass direction varies according to their position in the area. The angular directions of their longer axes cover nearly a half circle. In the district east of Lake Ontario they point east, that is they were shaped by a movement of the ice from the west. As we pass westward around the south side of Ontario we find the direction gradually shifting to southeast, then to south, and finally in western New York to southwest; while on the Niagara-Genesee prairie, in the northwest part of the State, the direction is southwest

by west. This radial direction is shown on the general map, plate 1, and the smaller maps, plates 5 to 17, show the attitude and forms within the 20 foot contours.

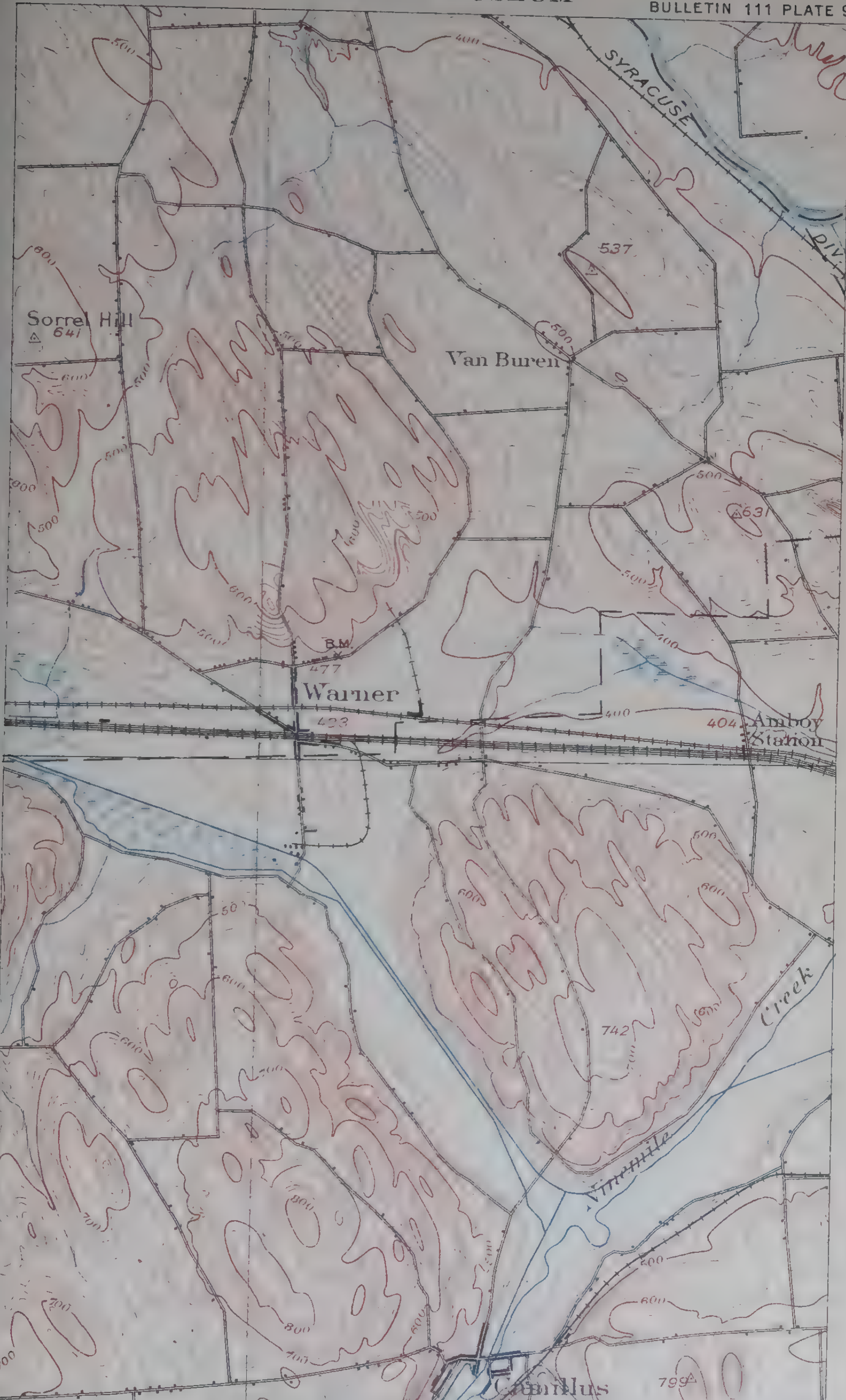
The long axes of the drumlins indicate the direction of the latest vigorous movement of the ice sheet in their locality, and the variant directions of the drumlins throughout the whole area prove a radial or spreading flow of the ice mass that rested in the Ontario basin during the stage of waning which is represented by the drumlin formation.

This consonance of the drumlin attitude to the latest ice flow direction is strikingly confirmed by the study of the drumlins in outlying districts. The Chautauqua drumlins point southeast, in harmony with the spreading flow of the Erian lobe of the waning ice sheet. On the other hand, the drumlins of the Watertown district, east of Lake Ontario, point southwest, conforming to the latest flow of the thinning ice in the St Lawrence valley.

Another interesting fact to be noted in this connection is that the axial direction is not always uniform along the same meridian. If the topographic control over the ice movement changed with the varying latitude of the ice front, as the latter was receding, the drumlins record that fact. For example, 20 miles south of Rochester the ice margin was guided by the Conesus, Hemlock and Honeoye valleys and the drumlins are north and south. But on the same meridian, only 6 to 12 miles south of Rochester, the drumlins point to the southwest, the ice margin being controlled by the Genesee valley and the thrust being from the northeast.

The radial or spreading flow of the ice at any single stage must be found by a comparison of the drumlin directions within a single series of drumlins, that is, drumlins which were formed simultaneously. If we take the second, or Oakfield-Syracuse, series we find the axial directions point as follows: At Oakfield, s. 55° to 60° w.; Fairport to Palmyra south; Syracuse, s. 30° e. Taking the third, or eastern Ontario, series, the drumlins are north and south at Sodus bay; at Oswego, s. 30° e.; Mexico, southeast; Pulaski, e. 20° s.; Sandy Creek, east.

A peculiar confirmation of the genetic relation between drumlin attitude and ice-flow direction is found in the Pulaski region. Passing northeastward around the corner of Lake Ontario (Mexico

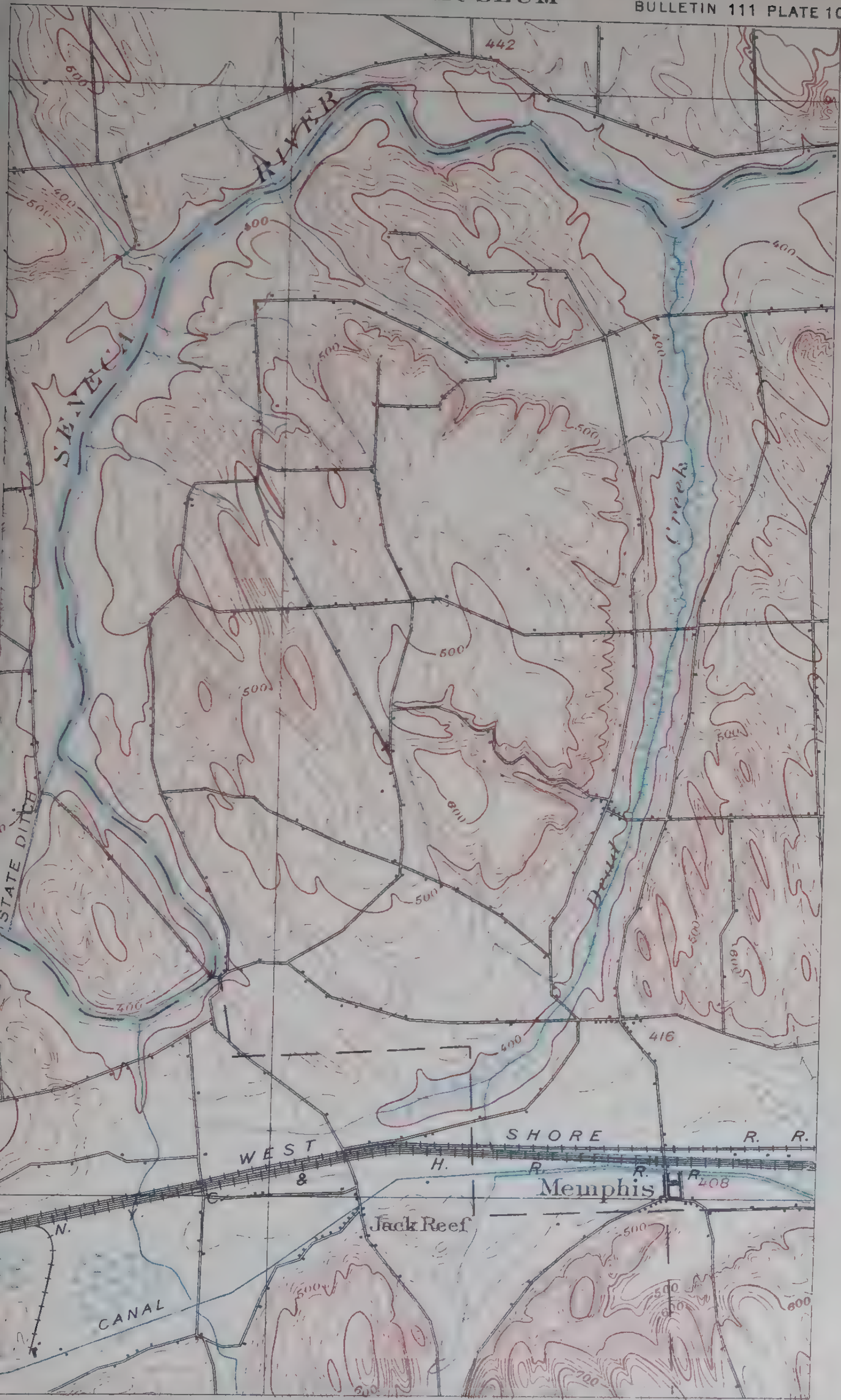


PART OF BALDWINSVILLE QUADRANGLE.

H. L. Fairchild 1905

DRUMLINS GROUPED IN ISLAND MASSES

The valleys are carved in Salina shale, which forms at least the base of the drumlins up to 500 feet or higher.



T OF BALDWINSVILLE QUADRANGLE.

H.L.Fairchild 1905

DRUMLOIDS

The drumlin-shaped forms in the upper part of the map are Salina (Vernon) shale.

bay) we find, as noted above, that the direction toward which the drumlins point veers from southeast to east. But as we pass on north some 10 miles, to Ellisburg and Belleville, we find the drumlins pointing southwest, or in direction nearly opposed to the drumlins between Oswego and Mexico.

These opposing directions represent ice-flow movement at different stages of the waning ice body. While the Ontarian mass yet covered the Oswego-Pulaski district the radial flow produced the forms which point southeast at Oswego and east at Sandy Creek. But during the latest stage of the ice in the basin the flow of the St Lawrence valley lobe produced the southwest-pointing forms between Ellisburg and Watertown.

It will now be recognized that if the southeast-pointing forms were made by an earlier flow of the same waning ice mass that produced the later southwest-directed forms then somewhere between the two opposing forms the drumlinized drift should indicate a turning, swinging or pivotal motion of the ice. As a matter of fact the drumlins in the district east of Mexico bay do show the complexity of form and direction required by the theory of ice movement stated above.[1]

Seen in the field, on the ground, the drumlins of the Pulaski district show peculiarities of form which the map contours do not suggest and which are puzzling and apparently inconsistent. The main drumlin forms, as shown on the map [pl. 5], point southeast to east. As seen from the north or south the characteristic profile is usually clear, but with change in point of view, looking from west or east, one sees instead of the expected end view or cross-section profile the peculiar longitudinal profile of the drumlin oval. Many of these contrawise forms should have received expression on the topographic sheets.

From whatever direction we view many of these hills the drumlin form appears. In many cases one detects a faint but distinct molding of the drift in direction highly inclined to the main form. Sometimes an irregular surface which is regarded as morainal becomes equivocal or even decidedly ice-molded with a change in point of view. There are patches of emphatic moraine surface and

1 This is not a case of finding that for which one is looking. The following observations relating to the peculiar forms of the Pulaski drumlins were made and the facts recorded as side notes while making special study of other phenomena, and their significance was not appreciated at the time.

in some areas, as north and west of Pulaski, the moraine character prevails. Frequently a drumlin form as viewed from some distance becomes irregular and morainal in minor relief on nearer view. Sometimes the moraine surface is equally puzzling; smooth ridging or ribbing making one doubtful whether to map the area as moraine or drumlinized drift. Such areas occur southwest of Pulaski [pl. 5] and northwest of Sandy Creek.

One important point which has a bearing on the origin of drumlins should be noted here. The secondary or contrawise forms do not seem to have been made by the cutting or carving of the primary forms but to have been produced by the addition or plastering on of the later form. The work seems to have been constructional, not erosional.

The explanation of these exceptional features would seem to be that the main and larger drumlin forms were made by the eastward motion of the ice; and that the minor molding, at a high angle and usually southward, was produced when the waning ice in this district felt directly the thrust from the St Lawrence valley. It does not appear that the molding of the drift is pronounced in directions intermediate between eastward and southward. Possibly while the ice flow was changing from eastward to southward it was not relatively so vigorous, but it is more probable that only the latest of the minor ridging is conspicuously preserved.

Relation to larger topography

A glance at plate 1 shows that the general drumlin area covers ground of all altitudes from the level of Lake Ontario (and they probably occur in the depths of Ontario) up to about 1700 feet; this highest edge of the drumlin belt lying west of Canandaigua lake [pl 16]. West of the Seneca valley they usually reach up to high ground, 1100 to 1500 feet. In the low north and south depression of the Seneca and Cayuga valleys, where we might expect them to be well developed, they are weak or wanting above 500 or 600 feet [pl. 3, fig 2]. While scattering drumlins may occur in poor form between the eastern members of the Finger lakes it may be emphatically stated that the area of close set and well developed drumlins does not reach south on the high ground east of Seneca lake, but that extensions of the drumlin area do reach up on the high ground west of Seneca lake and as far west as to the

PART OF WEEDSPORT QUADRANGLE.

TYPICAL OVAL DRUMLINS

H. L. Fairchild 1905

Tonawanda valley. This distribution of the drumlins indicates that altitude and grosser topography are not alone controlling factors in the drumlin formation.

The most massive development of the drumlins is on the low ground north of the Finger lakes, and chiefly under 500 feet altitude. This great development of the drumlins on the low Ontario plain and their comparative absence on the higher ground facing the ice sheet is most striking in the central and eastern part of the drumlin belt.

It is important to note that the district of highland drumlins, the western extension of the drumlin area, is where the later ice movement and the drumlin direction coincide with the general direction of the main ice movement, that is, toward the southwest; while the district of no elevated drumlins, east of Seneca valley, is where the drumlin direction is oblique or nearly at right angles to the direction of flow of the thicker ice.

The production or nonproduction of drumlins is believed to depend in part on the abundance and character of the bottom drift of the ice sheet, but chiefly on the active movement of the bottom ice, due to thrust from the rear. The absence of strong drumlins on the gently ascending slopes between Seneca and Owasco lakes may be partly due to the capacious preglacial valleys in the area north of the Finger lakes, which served as catchment for the lower drift. The absence of any large amount of drift, in the form of either drumlins or moraines, in the belt of open valleys [pl 2] suggests that the last ice which lay on this territory was comparatively clear of drift. It would seem that the greater burden of drift had been either rafted over the level of the open valleys to the higher valley heads moraine farther south, or was held in the lowest ice, and built into the drumlins farther north.

As stated above [p 369] the land surface east of Syracuse never felt the rubbing action of the ice sheet The Syracuse district was subjected to the thrust of a tongue of ice pushed southeastward from the spreading Ontarian mass. The southeastward and southward flow was not sufficient to reach the land surface over the Oneida lake region nor over the high ground east of Seneca valley. However, the land surface west of the Seneca valley, lying where the latest ice movement was the same as the principal ice movement,

toward the southwest, felt the molding effect of the ice thrust during the waning stage.

Relation to underlying rock strata

A glance at any stratigraphic map of New York State will show that the dominant drumlin area, north of the Finger lakes, lies on the low ground north of the outcrop of limestones formerly called Helderberg and Corniferous and over the belt of strata now known as Cayugan (Salina), Niagaran and Oswegan (Medina), naming them in descending stratigraphic order, or from south to north. These strata are chiefly shales, with relatively thin limestones in the Niagaran and some sandstone beds in the Oswegan.

The following table gives the approximate thickness of the several strata along the Cayuga meridian (corrections supplied by Mr C. A. Hartnagel of the State Geological Survey).

New York rocks along the Cayuga meridian

Divisions		Thickness in feet	Kind of rock
Erian	Hamilton	1 140	Shale
	Marcellus	80	Shale
Ulsterian	Onondaga	80	Limestone
Oriskanian	Oriskany	3	Sandstone
Cayugan	Manlius	70	Limestone
	Rondout		Limestone
	Cobleskill	6	Limestone
	Salina	1 400	Shale
Niagaran	Lockport	320	Limestone
	Rochester		Shale
	Clinton	80	Shale and limestone
Oswegan	Medina	950	Shale and sandstone
	Oswego	200	Sandstone
Cincinnatian	Lorraine	820	Shale
	Utica		Shale

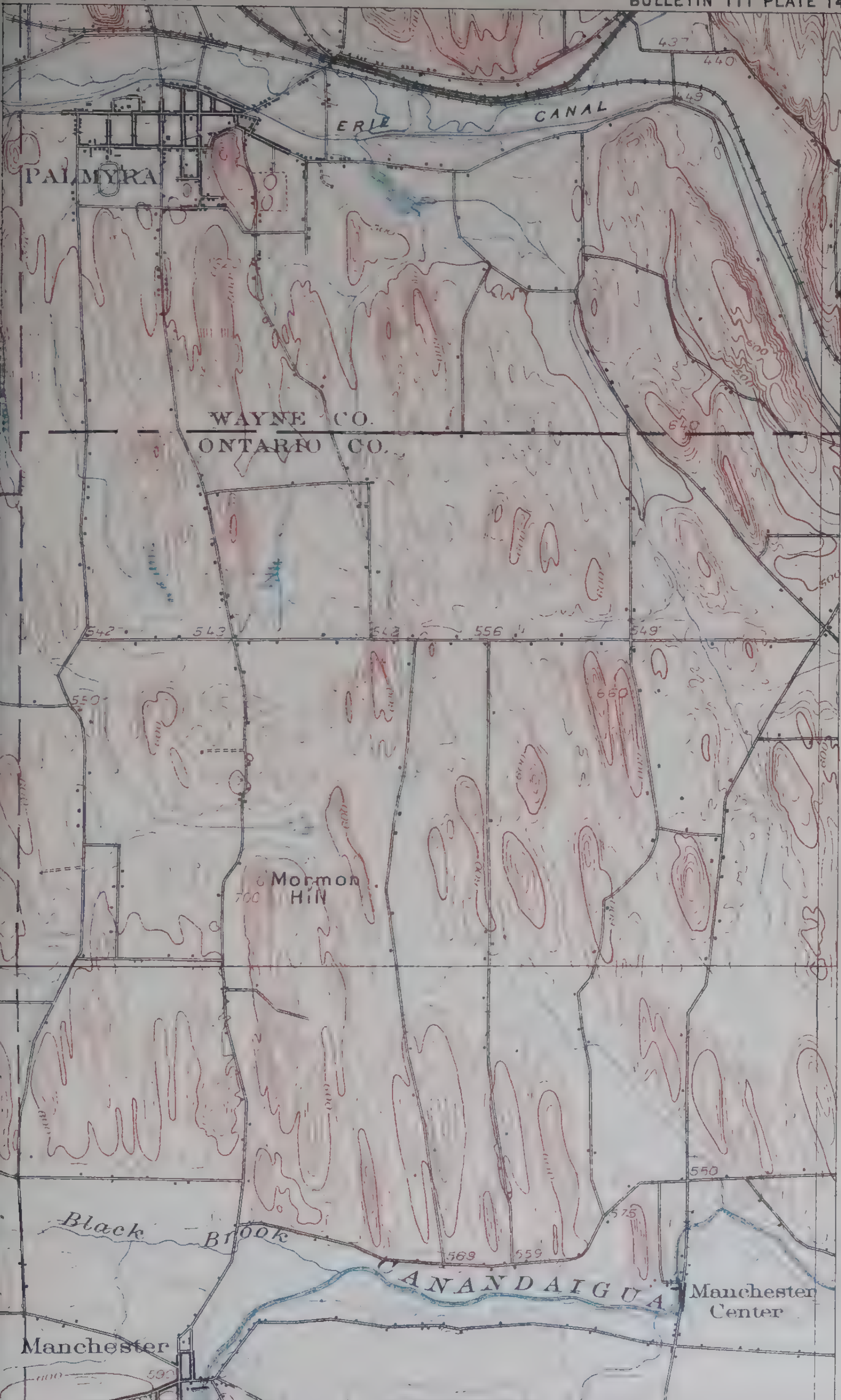
The drift supply for the drumlins of any district was derived mainly from the strata immediately northward. The above table shows that rocks beneath the limestones which inclose the Oriskany are mainly shales of great thickness. Counting the Medina as one fourth sandstone and the Niagaran as half limestone we have 3130 feet of shale, 200 feet of limestone and 440 feet of

RT OF CLYDE AND GENEVA QUADRANGLES.

H.L.Fairchild 1905

SOUTH EDGE OF THE MAIN DRUMLIN SERIES

The terminal moraine lies in front of the attenuated drumlin border.



PART OF PALMYRA AND PHELPS QUADRANGLES.

H.L.Fairchild 1905

DRUMLINS OF THE MORMON HILL GROUP

The south termination is abrupt against a glacial river channel.

sandstone. All these strata have a decided southward dip which gave outcrops projecting northward against the ice advance. By long eras of preglacial weathering these exposures of shale and limestone afforded a large supply of plastic drift to the bottom ice. It is believed that the rock rubbish was not in any stage of the ice work carried far away, but on the contrary was plastered into the drumlin masses. The thick clay strata supplied a burden of unusually clayey and adhesive drift; and it seems probable that the adhesive and plastic character of the lower drift was a contributory factor in the upbuilding of the drumlins, specially the taller ones.

Form and dimensions

These elements are very variable. The ordinary shape of the drumlins in western New York is an elongated oval, the length being three to five times the breadth. Occasionally they are short ovals, and rarely approach the mammillary form, but much more frequently they are long or attenuated ridges. The elongated or ridge form is the characteristic New York type, though other forms occur frequently, except the dome.

Considering horizontal dimensions the several types may be distinguished as the mammilla or dome; the oval; the slender oval or short ridge; and the linear or attenuated ridge. The two latter forms include the great majority of New York drumlins. It is an important fact that the several types are not intermingled but are separately grouped, certain districts exhibiting some particular type almost exclusively. This is fairly illustrated in selections from the topographic sheets; the oval form, large and small, being shown in plates 7 and 11, the Fairhaven, Syracuse and Weedsport districts; plates 12 and 14 showing the short ridges in the Clyde-Palmyra district; while the long ridges are shown in plates 6 and 19, the Oswego district and the Niagara-Genesee prairie. The very slender, linear ridges are often too low or weak to be shown by 20 foot contours, but an example which appears on the map is here given as plate 13, the district north of Waterloo and Seneca Falls.

The lengthwise profile of the shorter drumlins is an elegant curve, convex to the sky, and characteristically more abrupt or steeper at the north end. The crest line of the longer ridges is commonly almost a straight line, which appears to the eye as true as if cut to a "straightedge" [pl. 30]. The south ends of all drumlins,

except the steeper ovals and domes, taper off into the general sheet of till unless eroded by waves or other agency.

In cross-section the variation of profile is more limited than in longitudinal section. The summits naturally have a symmetric curve. Unsymmetric but yet convex summits may be produced by the drumlin process, but sharp crests, as in plates 29, 34 and 36 are regarded as an effect of later erosion. In some cases the erosion of the sides of the drumlin has gone so far as to gnaw into the summit and produce a scalloped or wavy or broken crest line. As a rule the shorter drumlins have the flatter cross-section profile, while the long and the linear ridges may have either a crest curve of short radius with steep side slopes or a broad summit and semicircular cross profile.

The junction of the convex drumlin with the horizontal ground surface naturally gives a concave slope at the drumlin base. Above this concave basal slope all drumlin surfaces are regarded as normally convex, and departures from convexity are due to some interference with the constructive process or to some subsequent effect. Two or more drumlins may overlap, or blend, or even be superposed [*see* p. 409] so as to produce irregular or unusual forms. Morainal drift is frequently banked against the sides and bases of the drumlins so as to change the true form. Erosion by the waters of glacial outflow may have cut the slopes and even the crests of drumlins, but decided crest cutting has been infrequently seen in New York, though conspicuous in Massachusetts.[1]

Vertical ridging or ribbing of the side of the drumlin is thought to be positively erosional, either by glacial waters or by postglacial storm wash and weathering. On the other hand longitudinal fluting or molding is regarded as a constructional effect of the drumlin-making progress.

With very few exceptions the drumlins are cleared of timber and their surfaces are under cultivation, as they afford the best soils. Some of the minor irregularities of surface may be subdued by the farm cultivation, but when the elements contributing to their erosion are considered it is remarkable that they are so well preserved. In the great majority of cases they seem to preserve their original form with practically their natural surfaces.

1 Barton, George H. Glacial Origin of Channels on Drumlins. Geol. Soc. Am. Bul. 6: 8–13.

WALWORTH DRUMLINS

Moraine drift is scattered among the drumlins, wholly replacing them on the north. The Iroquois beach ("Ridge road") forms, by erosion, the north limit of the moraine.

The type of form least exemplified in New York is the dome-shaped. While such may rarely be found they certainly do not characterize any district. The group of drumlins which most nearly approaches the mammillary form, judging from the topographic sheets, lies in the neighborhood of Fairhaven bay, and is partly shown in plate 7. The oval form is excellently shown on the Weedsport sheet [pl. 11]. The long oval or short ridge, the "dolphin back" shape, probably includes a majority of all the New York drumlins, and is the most widely distributed. A massive development may be seen on the Palmyra sheet, plate 4. Probably this form should be regarded as the typical drumlin form, from which the dome on the one hand and the linear ridge on the other are extreme variations.

The long drumlin ridges, which are specially pronounced in New York and are therefore regarded as the New York type, are well displayed on the Clyde, Auburn, Oswego and Brockport sheets. There are two extreme varieties of the ridge form, the large and the small. The large form includes broad, low swells or rolls which if lying alone or far separated may not be recognized as of drumlin nature. They are not often indicated by the map contouring. These low, broad moldings of the till are the common and only form over most of the surface of the Niagara-Genesee prairie. Passing west on the Rome, Watertown and Ogdensburg Railroad, the change can be readily seen from quite typical long drumlins near the Genesee river [pl. 18] to very long swells of low relief, which if not at all indicated by the 20 foot contours may be recognized by the shallow cuts for the railroad grade. Westward these rolls gradually fade into gentle undulations of the surface, quite imperceptible except by the up and down grades of the railroad. Large areas are perfectly flat to the eye. Buildings are visible for miles in different directions on the plain unless hidden by trees. The roads stretch great distances, ending to view only by the overarching shade trees or by a turn in direction. That this smooth country has been ice-molded is shown by the stream flow, which is northeast or decidedly oblique to the general slope. The low relief and the oblique stream control is well shown in plate 19.

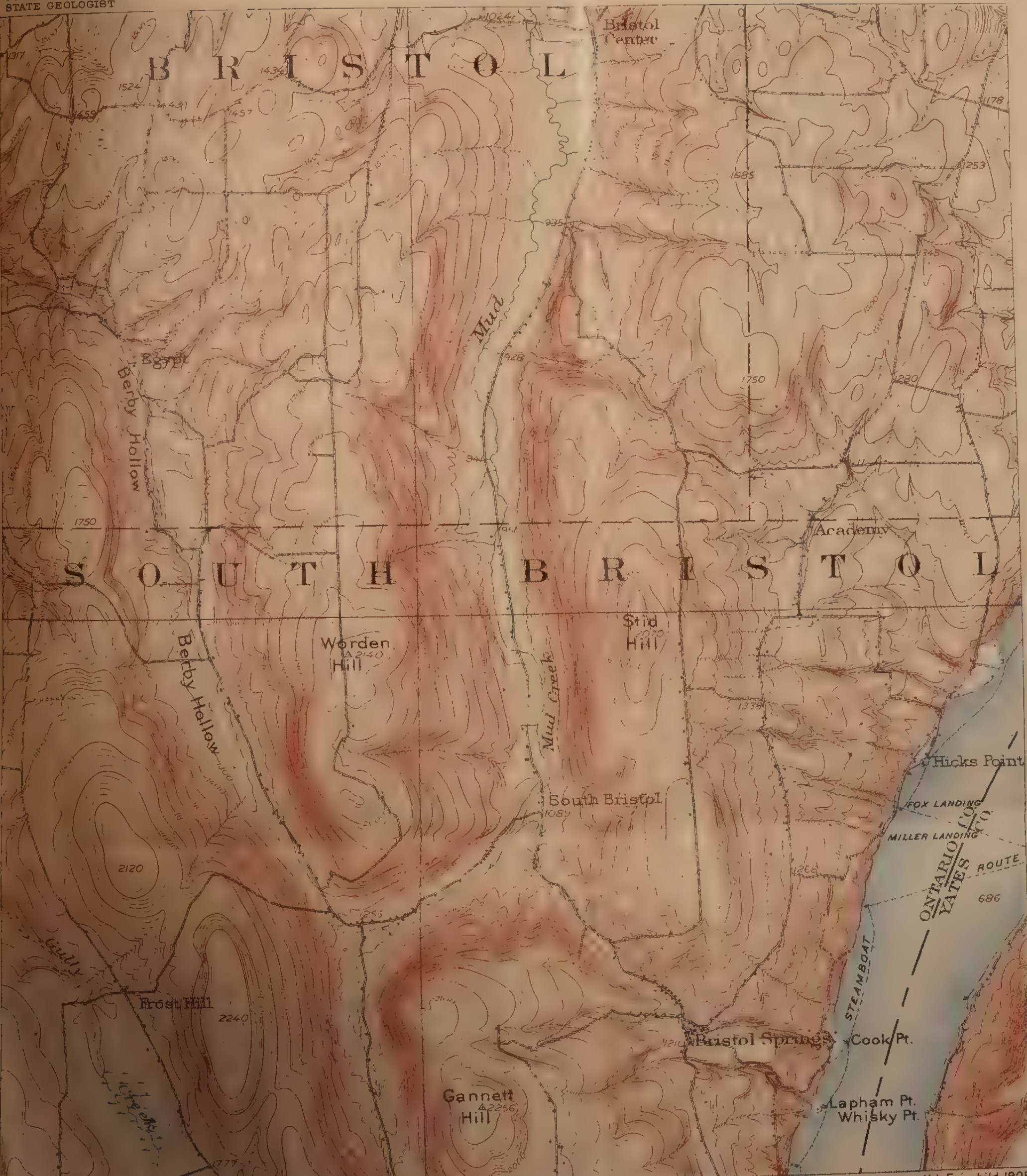
These southwest-pointing drumlin ridges occur in strong development southwest of Alden and west and southwest of Buffalo over

the lower and smoother plain. The contouring on the Erie county sheets, the Attica, Depew, Buffalo, and other quadrangles to the south, fails to properly indicate the drumlinizing of the land surface. As the ridges lie in the smooth country occupied by the glacial Lake Warren and the subsequent falling waters, and as they have the southwest direction parallel with the general contours and the lake shore lines, some of the smaller ridges are liable to be mistaken, in distant view, for huge wave-built bars or beaches.

The small variety of the long ridges is displayed in the Lyons-Clyde-Savannah district, where the primary drumlins include between them a secondary or minor order of ridges. These inferior ridges are straight, parallel, side by side, and often not larger than large railway embankments. They are not good subjects for photography but plates 32 and 33 are examples. These attenuated, intermediate ridges prove the molding action of the ice, and its drumlin-making tendency, even in the hollows between the larger structures. The major and minor ridges taken together suggest comparison with a piece of wood molding "struck" by the planing machine. This comparison is even better if we take the drumlins which exhibit longitudinal ribbing or fluting along their sides or bases. This longitudinal molding on the slopes of drumlins is certainly constructional and not due to any subsequent or erosional effect, as are the vertical forms.[1]

To the observant traveler on the railroads between Rochester and Syracuse the statement that the longitudinal drumlin profile is always convex seems untrue, because decided concave notching may be seen on both north and south ends of the drumlins. These are due to subsequent wave erosion by glacial lake waters. Some work of this kind was done at higher levels by the Warren and Dana waters [pl. 17], but the most conspicuous notching is in the area of the Iroquois waters. The pronounced erosive work illustrated on the shore of the living Ontario [pl. 7, 8] and along the "Ridge road" or ancient shore of the extinct Iroquois [pl. 4] may be seen in less degree but yet clearly between Lyons and Syracuse from the trains of the New York Central and the West Shore Railroads. Plates 36, 37 and 39 are views taken from the railroads.

1 Speaking of these ridges D. F. Lincoln has said: "From this they grade downward to little ridgelike elevations of 5 feet in hight and a furlong in length. Even these are quite distinct to the eye, rising from the uniformly level plain."



PART OF CANANDAIGUA AND NAPLES QUADRANGLES.

HIGH-LEVEL DRUMLINS BANKED AGAINST THE BRISTOL HILLS

The great Bristol hills are hard rocks and quite unaffected by the glacier. The drumlins southwest of Bristol Center are probably the highest above sea in western New York.

the eye, rising from the uniformly level plain.

This wave cutting of the drumlins which held their heads up as islands in the Iroquois waters seems capricious. Some drumlins which from their location must have been exposed to severe wave impact from the direction of the heaviest winds (mainly northwest) exhibited little effect, while others [pl. 38] which had more sheltered positions or were exposed only to southerly winds are decidedly cut. The amount of wave cutting seems to have depended in no small degree on the composition and texture of the till.

One singular effect of the end erosion of the isolated drumlins is to give a bent appearance to the cut end. Oblique erosion of the originally rounded end causes the crest line of the ridge to bend away abruptly, to the leeward, from the axial line of the hill. In some cases this change in the direction of the crest line is the best evidence of erosion, for it is believed that the original crest of the "stoss" or struck end of the drumlin must have been true to the axial line. Examples of these twisted-nose drumlins are rather poorly shown in plates 36 and 37.

A singular form of drumlin is found in the district south and southwest of Rochester, illustrated in plates 40 to 42. This suggests one drumlin superposed on another; a sort of two-story drumlin. They were first noted in connection with the search for evidences of Dana waters. Some of the concave slopes coincide with the Dana level and possibly the features have been rarely accentuated by wave erosion, but the form is found at other levels. Moreover, the surfaces of the two-story drumlins have the characters of ice molding, the lines are out of horizontality, and erosional characters wanting. The form is believed to be the product of the ice work, and perhaps due to two stages of the constructional process, or to a slight change in the direction of the ice movement.

These double-deck drumlins have been found only in the district at the north end of the larger Genesee valley, and on either side of the valley. It is suggested that the variation or change in the upbuilding process which caused this peculiarity in form may have been related to a change in the direction of ice flow due to the influence of the Genesee valley on the thinning ice sheet.

The cross profile of a drumlin is naturally subequal or symmetrical, but there is modification of the slopes when two or more drumlins lying close together, either side by side or in echelon, are crowded

in their growth or even blended. Asymmetry may be due to some local variation in the ice movement, apart from the crowding in construction.

Sometimes the drumlins have an outline when seen endwise that resembles the normal longitudinal profile. This abnormal form has been seen frequently in Wayne county west and northwest of Walworth [pl. 15]. This form is not due to change of ice flow direction (which accounts for the similar appearances in the Pulaski district) but to irregular construction, and perhaps to ultimate union of primarily distinct drumlins. In the dominant drumlin area the growing drumlins seem to have frequently fused together so as to give unbalanced cross-section profiles, but such drumlin masses have in longitudinal outline the characteristic curve.

Dimensions. The size and dimensions of drumlins are variable, within limits, according to the quantity and quality of the drift and the depth and impulse of the ice sheet. The smaller or infantile drumlins do not usually have good or characteristic forms unless they are of the slender type or small, attenuated ridges, which may be small in cross-section and yet retain a distinctive character as ice-molded till.

There seems to be a limit to the hight of individual drumlins, this being in New York about 200 feet. Using the map contours for determining the base of the drumlin as well as the summit altitude (an inexact basis, with maximum error of 40 feet) only one drumlin is found with altitude over 200 feet. At some point the upbuilding process is antagonized by the eroding or leveling tendency and a balance is struck between the opposing forces which limits extreme hight, and results, apparently, in the production of multiple ridges of moderate size instead of one huge ridge. This principle seems to be illustrated in the form of the peculiar groups in the Syracuse region, described later [p. 429 and pl. 9].

The most conspicuous drumlins, striking because of their isolation, like those rising out of the Montezuma marshes, are not the highest. Using the map contours, as noted above, for approximate data along with the figures frequently given on the map for definite altitudes of many higher drumlins, the following table has been compiled. This gives the approximate altitudes of base and summit and the individual hight of a considerable number of New York drumlins in different districts.

H.L.Fairchild 1905

PART OF ALBION QUADRANGLE.

ELBA DRUMLINS

The northern drumlins bear the gravel spits and wave-cut cliffs of Lake Dana, at about 700 feet. At about 880 feet, on the south edge of the map, is the shore of Lake Warren.

Altitude and hight of highest drumlins

Designation	Base and summit altitudes	Hight
Meridian of Rochester		
Rider hill, 2 m. n.w. of West Rush	620–800	180
Huckleberry hill, 2 m. w. of Lima	900–1054	154
Jakman hill, 2 m. n.e. of Livonia	1040–1194	154
? hill, 1 m. n.w. of Livonia	920–1080	160
Meridian of Palmyra and Macedon		
Pigeon hill, 2½ m. n.w. of Marion	480–665	185
Triangulation station, 4 m. s.w. of Canandaigua	1040–1201	160
? hill, 1 m. n. of Palmyra	480 633	150
? hill, 2 m. n.e. of Palmyra	500–670	170
[1] Mormon hill, 4 m. s. of Palmyra	600–700	100
Meridian of Sodus-Newark		
Triangulation station, ½ m. w. of Sodus	440–595	155
Triangulation station, 1 m. s.w. of Sodus	460–620	160
Zurich hill, 5 m. s. of Sodus	440–640	200
Baker hill, 6 m. s. of Sodus	460–680	220
Triangulation station, 2 m. s. of Clifton Springs	700–860	160
Meridian of Sodus bay-Clyde		
Chimney bluff, 2 m. e. of Sodus bay	250–400	150
? hill, 1 m. n.w. of Rose	420–600	180
Triangulation station, 2½ m. s. of Clyde	420–600	180
Meridian of Fairhaven		
? hill, 2 m. n.e. of Fairhaven	250–400	150
? hill, 4 m. s.e. of Montezuma	520–700	180
Meridian of Oswego-Weedsport-Auburn		
Triangulation station, 4 m. n.w. of Cato	400–567	167
? hill, 3 m. n. of Cato	440–620	180
? hill, 3 m. w. of Cato	420–600	180
? hill, 4 m. n. of Weedsport	440–620	180
Triangulation station, 2 m. s. of Weedsport	600–740	140
Meridian of Fulton-Jordan-Skaneateles		
? hill, 2 m. s. of Jordan	660–800	140
Cottle hill, 3 m. n.w. of Skaneateles	880–996	116
Region of Syracuse		
? hill, 3 m. n.w. of Camillus	700–860	160
? hill, 2 m. n.e. of Camillus	640–760	120
Triangulation station, 3 m. e. of Camillus	660–799	140
Triangulation station, 3 m. e. of Camillus	580–736	156
? hill, 3 m. s.e. of Syracuse	660–805	145

1 It is a singular coincidence that the celebrated drumlin, the "Mormon hill" [pl. 29, 30], in which Joseph Smith claimed to have found the golden plates of the *Book of Mormon*, should have as its altitude the centennial multiple of the sacred number seven, in English feet. The hight of the hill was not known until the recent topographic survey, but the Latter Day Saints may claim that their prophet had inspired knowledge or divine guidance.

It will be noted that only two drumlins in the above table lift their summits 200 feet above their platform, though several approach that hight.

The length of the drumlins is quite as variable as their hight, but it can not be well determined from the map contours, as a relief of less than 20 feet may carry a distinct ridge for a long distance. The long ridges of drumlinized drift which specially characterize the drift surface in the northwest corner of the State, including the Niagara-Genesee prairie, are almost unrecognized by the topographic map.

Scores of drumlins can be found on the map with a contoured length of a mile, or even a mile and a quarter. A length of 1½ miles is not rare, but 2 miles is extreme. Perhaps the longest well contoured forms are in the Oswego district, shown in plate 6.

The very long drumlins are sometimes produced by the close welding of overlapping ridges.

Composition and structure

The material composing the New York drumlins is very compact till. The writer recollects only one or two instances in which water-laid drift has been found unequivocally incorporated in the drumlin mass. Gravel and sand are frequently found on the flanks of the drumlins, specially where they were exposed to wave work of the glacial lakes, but the experienced observer could never mistake this for drumlin material. Water-laid drift may be expected on the surface of the drumlins as an occasional product of superficial stream work at or near the ice border. In morainal areas the marginal drift, kame or till, may be scattered on and among the drumlins, and sometimes in such abundance as to obscure or perhaps partially bury the drumlin forms. Such a case is found in the Junius kame moraine, midway between Geneva and Lyons. However, this superficial morainal drift must not be mistaken for nor confused with the drumlin material, as it is not only emphatically distinct in its genesis from the subglacial drumlin mass but subsequent in time of deposition.

Only two instances have been found by the writer of water-laid drift distinctly within the drumlin mass. In the northeast edge of the village of Lyons, on Phelps st., a small drumlinlike ridge of till about 500 feet long and 150 feet wide, lying on the east flank of a

about 480 feet, judging from the map contours. In the region of

the village of Lyons, on Phelps st., a small drumlinlike ridge of till about 500 feet long and 150 feet wide, lying on the east flank of a

larger drumlin ridge, has 15 feet depth of till over a base of sand; but the sand substratum is restricted to the small ridge.

In a recent extensive examination of the internal structure of drumlins, to be described below, a bed of sand was found in the interior mass of a drumlin, situated 2 miles northeast of Fairhaven bay and south of Juniper pond. The waves of Lake Ontario have dissected the drumlin obliquely, exposing a section of till about 100 feet high. About midway in the hight of the cliff is an irregular layer of sand, 2 to 3 feet thick and of considerable but indefinite extent. The sand shows no clear bedding and seems to have been crushed and worked over by the ice rubbing. The extreme rarity of such inclusions of water-laid drift in the drumlins of New York is a conclusive argument against the theory that they are erosional forms, produced by overriding and reshaping of terminal moraines. This point will be discussed later.

The drumlin till, specially in the deeper layers, is decidedly more compact and harder than the ordinary sheet till, and the included stones of all sizes are more generally abraded. The material gives evidence of movement under pressure; it is emphatically the glacial grist.

The proportion of crystalline and far-brought material is apparently less than in terminal moraine deposits, but examination has not been sufficiently thorough to indicate percentages. In any belt it will probably be found that the proportion of material derived from the subjacent strata or the rocks immediately northward is larger in the drumlins than in the moraines. In other words, drumlins represent, at least in central New York, the subglacial or "ground moraine" drift.

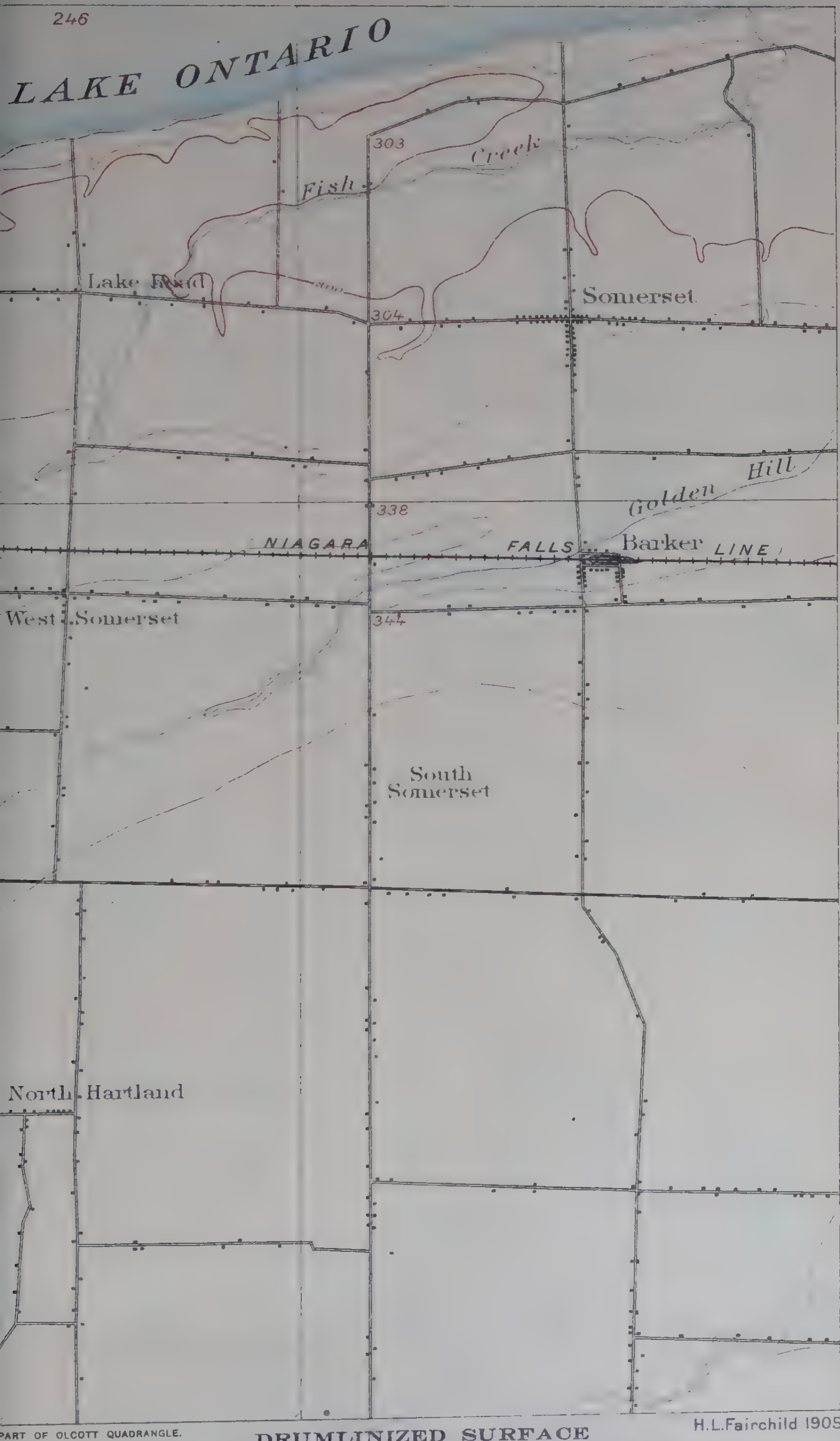
Rocdrumlins. Between Palmyra and Syracuse the foundation of the drumlins is Salina shale, mostly the soft red and green beds called Vernon shales. All the deeper valleys are cut in this shale, which may be seen on the slopes as bare patches of bright colors, red and light green. An excellent exposure may be seen at the "blue cut" on the south side of the West Shore and the New York Central Railroads midway between Newark and Lyons; and at the time of this writing (September 1905) the electric road building in that district is making many exposures. At the "blue cut" the Vernon reaches 60 feet above the railroad, or to the hight of about 480 feet, judging from the map contours. In the region of

Jordan and Memphis these shales forming the walls and bottom of the broad valley are eroded into forms simulating morainal topography. (This resemblance of the shale erosion forms to moraines is very pronounced all the way east to Oneida, and even the experienced geologist who is new to the region will make wrong diagnosis if he decides by the forms as seen from a distance.)

In the Jordan-Memphis district the Vernon shales reach up over 500 feet, while the lake and stream fillings in the valleys are about 400 feet altitude. The Vernon shales, therefore, extend upward about 100 feet above the lowlands and are overlain by the somewhat harder but yet soft gypsum-bearing Camillus shales. East of Jordan they form the common platform from which the drumlins rise [pl. 9, 10]. But west of Jordan, as far at least as Newark, the drumlins are situated much lower, their bases being contoured [pl. 11, 12] by the 400 or 420 foot contour, and many rising out of the Montezuma marshes as if partly buried under lake deposits. It appears, therefore, that in the Weedsport-Lyons belt the Vernon and Camillus shales belong in the same horizontal plane or topographic horizon as the drumlins, and the interesting and important question arises if the drumlin forms may not be partly shale instead of till. Some study of this problem has been made with definite results. The drumlins show only till at the surface, in nearly all cases. Often this may be only a veneer or varnish of drift rubbed into the soft shale. The West Shore Railroad has several good cuttings through drumlins in the stretch west of Port Byron which ought to reveal interior composition and structure, but the cut slopes are so coated with wash from the upper material that to casual inspection they appear as till.

One and one half miles northeast of Port Byron the red Vernon shales appear clearly on the slopes and at the summit of a drumlin-shaped hill having a summit contour of 460 feet. This hill is indicated in the lower left hand corner of plate 11. Here we certainly have a drumlin form in rock, a rocdrumlin. It is very likely that other of the lower drumlin forms may be chiefly shale with only a veneer of drift, and it is more than likely that some of the larger drumlins have a base or core of shale.

All the western central New York rocks have a decided southerly dip. It is evident, therefore, that north of the Syracuse-Lyons parallel the strata should lie at increasingly higher elevation.



DRUMLINIZED SURFACE

Near the west end of the Niagara-Genesee prairie. *Compare plate* 18. The ice-molding carries the streams oblique to the slope. Surface smoothed by Iroquois waters.

The vertical or stratigraphical range of the Vernon shales, which are several hundred feet in thickness (the thickness of the whole group of Salina shales is about 1400 feet, *see* page 404) would include the whole hight of all the drumlin forms in a considerable belt of territory. An examination was made of the hills west of Baldwinsville with a result not unexpected. It was found that all the drumlin forms are clearly composed of red shale, with only an apology of till covering. All the hills in the upper half of the map, plate 10, and lying between the two north-leading valleys are known to be not drumlins but rocdrumlins.

At first sight these hills would be regarded without question as true drumlins, but there are decided though refined differences which appear on closer study. The rocdrumlins are not so symmetrical as the till forms; the slopes are less regular; and the struck ends are liable to be more abrupt and irregular and with less convexity. The differences are clear when once recognized, and are fundamental. The 20 foot contours of the map even reveal a difference. Looking at plate 10 it will be noted that the bases of the hills are indefinite, and that as hills they do not possess the strong individuality of the drumlins, as shown in plates 11 and 16, for example.

These Vernon shales are only hardened clays, without structure and very easily decomposed.[1] They yield more readily to weathering and probably to erosion than any other rock, and the product of the ice rubbing was doubtless a lubricant and plastic paste essentially like clayey till in its mechanical properties. In consequence the hills of Vernon shale which stood within the zone of drumlin formation, in the conflict with the moving ice, were more easily shaped into the drumlin form than other rocks, but when given that shape they resisted the ice impact better than harder rocks. These shale hills were at the same time more compliant and more resistant. They became drumlins in effect though not in origin. They are erosional forms, while drumlins are constructional forms.

The soft Vernon shales extend westward through the State but nowhere appear so prominently at the surface as in the region described above. Eight miles south of Rochester they are exposed at about 570 feet altitude. It is apparent that along their east and

1 The rapidity with which these shales weather to mud was the cause of dispute and litigation in the matter of the deepening of the Erie canal a few years since. The contractors justly regarded the shale as "rock" and charged for rock excavation; but inspection a few months later found the spoil banks to be only clay rubbish.

west outcrop they have been eroded by weathering and ice rubbing and the belt of outcrop deeply covered with drift. Their more common appearance on the Newark-Syracuse parallel is partly due to greater thickness and also to the postglacial excavation by the ice border drainage. The Salina shales as a whole, many hundreds of feet in thickness throughout the drumlin area, have supplied a large amount of plastic and adhesive material for the drumlin construction process, and may be one factor in the production of the drumlins.

Concentric bedding. If drumlins are constructional forms, that is, were built up by a plastering-on process, then it should be expected that on cross-section they would reveal some concentric bedding or onion structure, with the upper layers parallel to the drumlin surface. Theoretically the bedding need not be conspicuous as there could not have been great variation in the constructive process, as compared with the work of water, in either kind or quality of material or in rate of deposition. The comparative uniformity in the work of the ice, taken in connection with the heterogeneous character of the till, would seem unfavorable to any conspicuous structure.

Few cuttings in drumlins expose large sectional areas, and such as do occur can commonly be seen only at close range, which is unfavorable to inspection of indefinite and large-scale structures. To recognize the general structure it is necessary to have a comprehensive view, yet not so distant as to obscure all details.

Bedded structure in drumlins has been casually noted in a few instances but the only description of such feature (in the writer's knowledge) has been given by Upham, of a few drumlins on the Massachusetts coast at Scituate and in the neighborhood of Boston, which have been dissected by wave erosion.[1]

The most favorable exposure of interior structure of drumlins known to the writer is found along the south shore of Lake Ontario, and specially between Sodus bay and Oswego. In this stretch of about 28 miles not less than a score of drumlins, many of large size, are dissected to their core by the wave erosion. The constant undercutting by the waves [pl. 8, 43–46] yields continually fresh sections from top to bottom, and fortunately in different directions. Some drumlins are cut in direct cross-section; some in oblique

1 *See* titles on page 438 for the years 1888, 1889 and 1892.

PART OF DUNKIRK QUADRANGLE

H.L.Fairchild 1905

CHAUTAUQUA DRUMLINS

This area was molded by southeastward flow of the later ice, spreading from the Erie basin.

section; and some in longitudinal section. One could not reasonably ask for more favorable exposure than nature here affords.

The structure can not be seen properly at close range from the beach, nor at the long range from the steamers. In August 1905 the writer secured the help of an oarsman and with a small boat examined the entire shore from Sodus bay to Oswego. Part of this stretch was reexamined in September, and the study carried westward from Sodus bay. Many photographs[1] were taken, some of which are produced in plates 43 to 46.

The erosion cliffs range in hight from 20 feet up to 140 feet. The growth of vegetation is rarely sufficient to obscure the structure, and in some cases is in itself a proof of the till bedding, as it lies in horizontal lines. The higher cliffs are all bare.

More than half of the cliffs show undoubted concentric bedding and in several it is surprisingly distinct. At distances which minimize the relief of the cliff faces, in buttresses, reentrants, and amphitheaters [pl. 43], the fact of bedding parallel with the drumlin surface is strikingly evident, and is shown in different ways. A difference in the texture of the beds is apparent even at close range. Distinct zones or lines of boulders are often seen. A difference in shade of color is common, and the shading due to varying capacity for moisture is pronounced. The latter is also shown by patches of vegetation clinging along certain zones. The second cliff east of Sodus bay, "Cline's bluff," shows at even 2 miles distance a conspicuous line of vegetation. A most striking proof of bedded structure is shown by the differences in weathering, which are often indicated, as in plate 46, by the uniformity in hight on the cliff face of the conical buttresses. Two other cliffs which show this feature well are: one east of Juniper pond and 2 miles east of Fairhaven bay, which shows three lines of erosion cones; and

---

1The first photographs were taken with an ordinary shutter which proved too slow with the tossing of the boat. These first photographs show clearly the bedded structure but they are too blurred to be suitable for reproduction. For the second trip the Bausch & Lomb Optical Company kindly loaned a "Plastigmat" lens and a "Volute" shutter, and the photographs of plates 43 to 46 represent an exposure of 1-150 of a second, in the hazy light of the last day of September. The camera was a 5x7 Cartridge kodak, the only camera which the writer has used in six years.

When these views were taken the drumlin sections were very dry and the hygroscopic differences in the till layers did not show as well as they do soon after a heavy rain. Much better views can be obtained when all conditions are favorable, as quiet water of the lake, good lighting and the cliff faces in best condition.

To Mr W. R. Walsh of Sodus Point the writer's thanks are due for valuable assistance.

another a mile northeast of the mouth of Eighteenmile creek and about 5 miles southwest of Oswego.

In cross-section view the concentric bedding decreases in convexity passing downward toward the bottom of the drumlin. In other words, the bedding near the base of the drumlin is quite horizontal or slightly arched; and the arching increases with hight until near the top the layers are parallel with the drumlin profile. In some instances, particularly toward Oswego, the sections exhibit a superficial bed, estimated at 10 to 20 feet thick, of a lighter color and yellowish shade, and apparently less compact than the deeper blue-gray till. This superficial bed weathers into smoother or more uniform faces, instead of the projections, pinnacles, towers, or battlemented forms of the deeper and harder till.

A good test, and a confirmation, of the concentric structure is found in the oblique and the nearly longitudinal sections. A glance at plates 7 and 8 will show how the lake erosion is cutting the drumlins at very different angles. It is found that the stratification exposed in these different sections has the direction which would correspond to a concentric bedding. In sections approaching the longitudinal the bedding is quite straight and declines parallel with the crest of the drumlin toward the tail of the hill. In general the upper beds are parallel with the cliff profile and have the curvature appropriate to the angle of the section.

The application of these facts of drumlin structure to the problem of drumlin origin will be found in a later chapter. To facilitate the study of the subject by any one who wishes to examine the drumlin sections for himself the following notes and directions are supplied.

West of Sodus bay (the Pultneyville sheet) the cliffs are partly morainal and only two good drumlin sections occur, one of them being shown in plate 46. East of Sodus bay the lake shore is included in the Sodus bay sheet, reproduced in plate 8, and the Oswego sheet, partly shown in plate 7. These maps show approximately the angle of the wave cutting with reference to the drumlin axes.

The drumlins which display the bedded structure in the clearest manner are, taken in order eastward: Lake bluff (using the local names) [pl. 44]; Cline's bluff, 1 mile east of Lake bluff; Blind Bay bluff, 1½ miles east of East bay [pl. 45]; two cliffs either side of Juniper pond, which lies 2 miles beyond Fairhaven bay; and the

Plate 22

Drumlin 1 mile west of Lily Dale. View looking east

Plate 23

Drumlin 1 mile south of Lincoln, Wayne co. View looking south of west

Plate 24

Wayne county drumlins, town of Walworth. Looking west from Freeville hill

two cliffs midway between Eighteenmile and Rice creeks, southwest of Oswego.

The best longitudinal sections are the one east of Juniper pond and the one halfway between Eighteenmile and Rice creeks. The lighter colored top layer is well shown in the three cliffs east of Port bay.

It should be understood that the distinctness of the bedding varies with the degree of moisture and the lighting; and that it may be subject to change with depth of cutting and so vary with time.

Formation: theoretical mechanics

Thus far this writing has been of a descriptive character with only a modicum of reasonable inference. It is now time to take up the philosophical side of the study and if possible explain the origin and manner of making of the drumlins. In the earlier writings on these structures the question of their genesis naturally received much attention, but without confident conclusions. Probably no geologist doubts their glacial genesis but the precise manner of their formation has been in question. Two general views have been held, one that they are overridden and reshaped moraine drift, the other that they are constructional forms, built up ab initio by the moving ice out of its ground moraine or interglacial drift. That they received their form by the molding effect of the overriding ice sheet seems too evident to be questioned.

The idea that drumlins were primarily moraine masses may be true of some drumlins, and possibly of some forms in New York; but it certainly does not apply to them in general. The distribution of the drumlins is not in accord with the theoretical location of any former morainal belts; and this conception takes no account of isolated drumlins in some regions, or groups of drumlins far removed from suggestions of other drift masses. Moraine deposits are expected to lie in continuous belts. Furthermore, no moraines of such breadth and quantity of drift as are held in the Rochester-Syracuse drumlin area are found in New York, probably not in the Eastern States.[1]

---

[1] It should be admitted that the full history of the ice work in New York and New England is doubtless more complex than we now realize, and that probably there was ice invasion with its attendant frontal waters previous to the Wisconsin epoch. We now see the deposits as the last ice sheet left them, and while we must take the phenomena as we find them and study them as they lie we must not ignore the probability of an antecedent and different condition. However, it would be unscientific to minimize the facts before us and magnify the unknown or theoretical features.

Considering the great volume of water-laid drift commonly associated with the New York moraines, amounting in many cases to almost the entire mass, it would seem certain that the drumlins in the same territory, if overridden and reshaped moraines, should frequently if not habitually hold sands and gravels as a part of their mass ; in other words they should have the irregular structure and miscellaneous composition of the moraines. Indeed it would seem likely that with the volume of deep-seated waters in the marginal portions of the ice sheet (the streams either subglacial or in deep trenches) aqueous deposits might not infrequently be left beneath the ice in such position as to be incorporated into the drumlin mass. However, as stated above [p. 412], this feature is remarkably rare. Drumlins may be built on other antecedent drift, and stream or lake deposits may occur on their surface, but the drumlin material in the area under discussion is very compact till, and may be distinctly bedded.

The facts pertaining to the drumlins of New York are only consistent with the theory of their constructional origin. And now we have the sufficient proof that at least a great number of them were slowly built up by a plastering-on process, as described above [p. 416].

Since we know that the Sodus bay-Oswego drumlins are constructional it is a legitimate assumption that other drumlins in contiguous areas have the same origin. In the further discussion of the New York drumlins their constructional origin will be assumed.[1]

In the theoretical discussion of the mechanics of drumlin construction three sets of factors are recognized : (*a*) those pertaining to the ice itself, (*b*) those relating to the drumlin-forming drift, and (*c*) the external influences of topography and climate. These will be briefly considered in the above order.

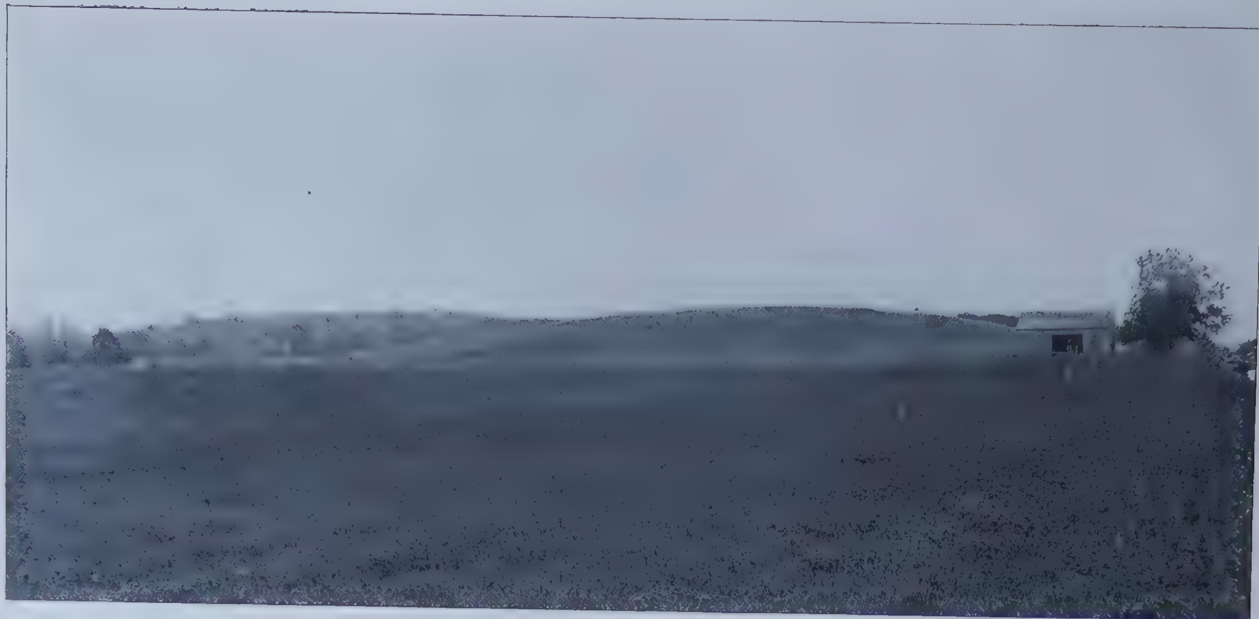
a Dynamic factors pertaining to the ice body

1 *Vertical pressure*, which is directly proportionate to the vertical thickness of the ice sheet.

2 *Horizontal pressure*. At the periphery of the continental ice sheet the horizontal pressure necessary to produce flow on level

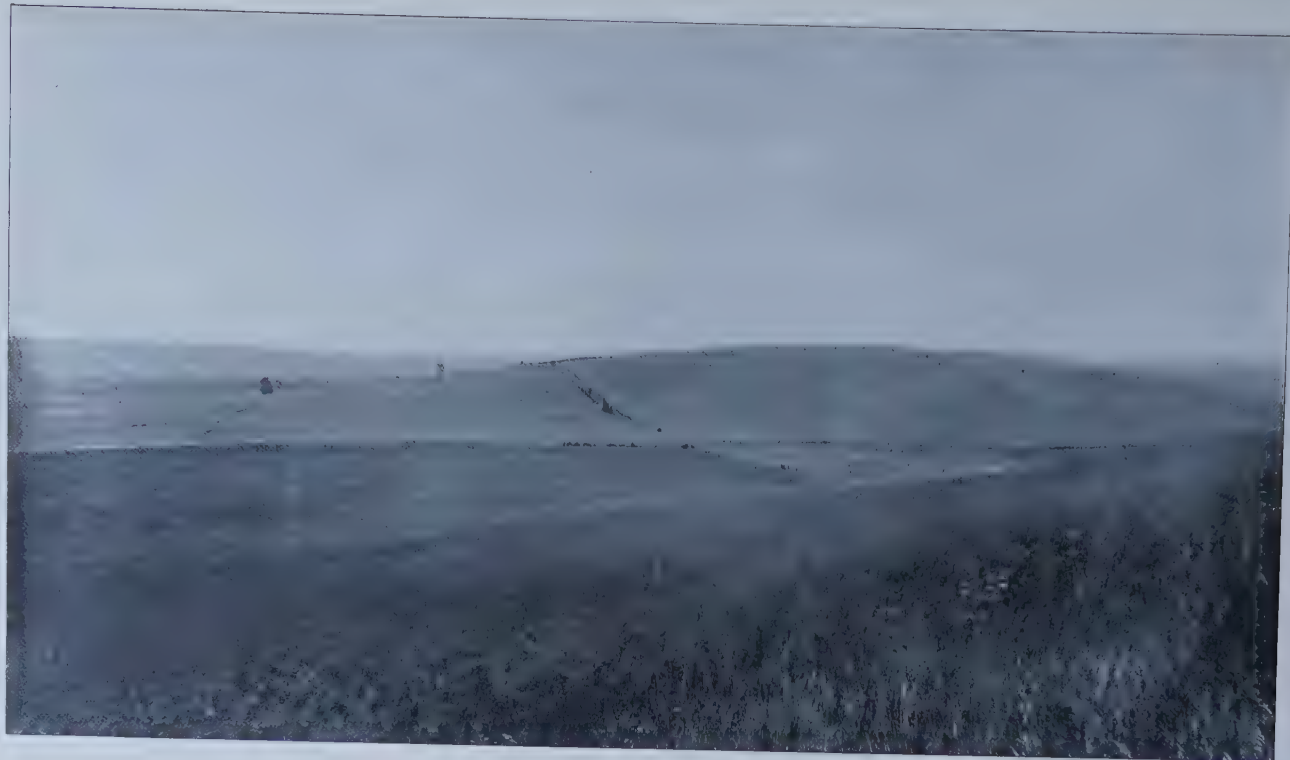
1 Since these lines were written it has been found that sections of drumlins in Oakfield cemetery, Syracuse, exhibit excellent bedding.

Plate 25



Wayne county drumlins. 3 miles north of Walworth. Looking east of south

Plate 26



Drumlin 1 mile east of Elbridge. Looking south of east. Same point of view as in plate 27

Plate 27

Drumlins north of Elbridge. Endwise view. Looking west of north. Same point of view as in plate 26

ground or on an up slope (as in the New York drumlin area) was mainly an effect of the vertical pressure in the deeper and rearward part of the mass. The depth of the ice sheet along the drumlin-making zone was probably insufficient to greatly aid the forward movement; but to the degree that plasticity was effective the vertical pressure might have had some effect in modifying the movement or in producing differential flow.

3 *Vigor and velocity of flow.* This is due primarily to the thrust from the direction of the deeper ice. The horizontal displacement or mass movement of the ice would be influenced by the larger features of the land surface and by the local temperature and rainfall [see *c*].

4 *Differential flow.* The practical plasticity of the ice would theoretically seem to allow unequal flow, or a tendency to flow in prisms or currents analogous to stream currents; and the drumlins are evidence of such local variations in the ice work.

5 *Plasticity.* This property of glacier ice would probably be increased by pressure, heat and water supply as a lubricant. In the marginal, drumlin-forming zone of the ice sheet plasticity due to vertical pressure would be reduced, that due to horizontal pressure would be fairly constant, while that due to heat and rainfall perhaps would be increased.

b Factors relating to the drift held in the ice

1 *Volume of the drift.* It has been recognized that plastic flow of glacier ice diminishes with increase of rock debris. But the movement of the lower ice by rearward thrust would not be so greatly affected by the contained drift. The influence of the drift toward rigidity might assist in producing differential flow in prisms or bolts. Whatever might be the effects on the flow of the ice by variation in the load of drift its abundance in the lower ice would seem to be a direct aid to drumlin building.

2 *Position of the drift.* The vertical location of the rock rubbish in the ice seems an important factor. Debris superficial to the ice sheet could only produce morainal masses. Drumlins must have been built from the debris carried in the lower layers of the ice.

3 *Quality of the drift.* It would appear that a clayey, adhesive character of the drift would facilitate the plastering on process, by which the New York drumlins are certainly made. No drumlins are found composed largely of boulders and friable material.

c Factors of external control

1 *General land slope.* A down slope would favor movement of the ice both by thrust and by plastic flow of the upper over the lower layers. An up slope would probably retard or prohibit motion at the bottom except by thrust. The great drumlin area of New York has an up slope, but the dominant minor area is nearly level. The Chautauqua drumlins are on high ground, very irregular but broadly level.

2 *Minor topography.* This factor is indefinite and uncertain because variable in many ways. It would seem that great irregularity of the overridden land surface would be unfavorable to movement of the lower ice, and the drumlin-making motion would lie more in the plane of the hilltops. (This has a bearing on the construction of the Syracuse island masses, page 425.) Small prominences in the bed of the ice sheet might be favorable as nuclei for the initiation of drumlins.

3 *Temperature and water supply.* Plasticity of the ice would be favored by heat and water. Cold and dryness favor rigidity. The margin of the ice sheet must have had nearly the highest possible temperature and the largest supply of lubricating water, from rainfall and ice melting. This would be quite independent of latitude as the ice can not be warmed above the melting point.

It is apparent that the drumlin-building process involves many factors, and most of them indeterminate. The problem is exceedingly complicated, including not only the difficult subject of the behavior of plastic solids but the action of the plastic ice under a complexity of geologic conditions.

Drumlin forms and observed relations. The interaction of the physical and geologic factors noted above has produced a great variety of drift forms which we may include under the general class of *ice-molded*, or *drumlinized drift.* These forms have been described or noted in the writing above, but it is well to name them here for comparison.

1 Domes or mammillary hills and low broad mounds.
2 Broad oval drumlins [pl. 7].
3 Oval drumlins of high relief [pl. 11].
4 Long oval drumlins, commonly bolder on the north or struck end; the dolphinback or whaleback hills [pl. 14].
5 Short ridge drumlins [pl. 6].

Endwise view of drumlins 3 miles southeast of Syracuse. Looking east of south from St Vincent de Paul Church, Syracuse. These drumlins are the southeast extremity of the drumlin area.

Plate 29

Mormon hill. Drumlin 4 miles south of Palmyra. End view looking south. Compare plate 30

Plate 30

Mormon hill. Drumlin 4 miles south of Palmyra. Side views taken from same point. Compare plate 29. Upper, view looking northeast; lower, view looking east

6 Long ridge drumlins. This includes two extreme varieties of form: (*a*) the long broad ridges or rolls or gentle swells which are not generally recognized as belonging in the drumlin class, and commonly fail of representation on the contoured maps [pl. 18]; (*b*) the small, close-set, parallel ridges which lie as minor moldings between the larger and conspicuous ridge drumlins, or those which form the attenuated edge of a drumlin belt [pl. 13].

7 Abrupt struck slopes [pl. 30, 35, 40].

8 Low or gentle struck slopes [pl. 22, 23].

9 Sharp crested hills with steep, or even concave, side slopes [pl. 29.]

Many occasional or peculiar forms and characters might be noted but they are not regarded as genetically important.

The relationships of the several forms are not so definite or exclusive as might be expected, though further study may discover new facts. However, there are certain broad relations of distribution and association which will be restated here.

1 The drumlin area is practically restricted to the north-facing or ice-opposing slope.

2 The region of greatest development of drumlins is on the low Ontario plain, which is nearly level.

3 The greatest development lies over the greatest thickness of the Salina shales, or where the drift is most clayey and adhesive.

4 The predominant drumlin area lies where the ice flow was east of south and at a high angle with the general southwesterly flow.

5 The somewhat exclusive development of the long and low ridges (6 *a*) is in the northwest corner of the State where the ice had only the one direction (southwest) of flow, but where there was less volume of clayey drift because less thickness of eroded shales.

6 The individual drumlins are not placed in any orderly sequence or regular disposition, but are irregularly spaced.

7 Within the same belt of drumlins or what is regarded as a formational unit the south forms or those nearer the ice border are more attenuated, while the north forms or those under the deeper ice are broader.

8 A belt of moraine drift lies in front of the attenuated border of the drumlin belt.

9 The greater hight of the drumlins, their steepness of slope and

regularity of form seem to occur in the middle of the belt and to characterize the maximum work of the constructive process.

10 Steep struck slopes seem to be more commonly associated with the steep and long ridges; while the low struck slopes pertain to the lower and broader forms.

Relation to moraines

The precise relation of the several drumlin belts to the terminal (recessional) moraines can not be fully stated until further careful study has been given to the moraines, but a few interesting facts can now be given.

If the drumlins specially represent the more vigorous movement of the bottom ice during episodes of either frontal advance or halts in the frontal recession then each drumlin belt should correlate with a frontal moraine.[1] Such relationship seems definite for the central or main drumlin belt, the Oakfield-Syracuse series, in the stretch from Syracuse westward as far as the meridian of Rochester. Where the drumlins fade out to the attenuated forms, from Auburn westward to Geneva, a distinct moraine lies 2 or 3 miles in front, on the south [pl. 13]. Remnants of the moraine mark its course eastward to Split Rock, southwest of Syracuse, but in the Split Rock district the ice front was swept by rivers of ice border drainage and the ice-rafted drift was largely dropped into the grasp of the streams. West of Geneva the same relation of drainage to the ice front is very pronounced. A remarkable series of strong river-cut channels extending from northwest of Batavia eastward to Phelps swept the ice margin and removed most of the terminal drift, though some remnants are left, sufficient to prove its position.[2]

The interesting fact in this connection is that the drumlins of the main series reach in full strength up to the north bank of these channels [pl. 9, 11, 14] and there abruptly end. The drainage channels do not represent the forward position to which the ice would have reached with no interference (or the location of the moraine

1 The theory is now held by glacialists that the front of the continental glacier receded by oscillation, a succession of retreats and lesser readvances, and that the stronger moraines were accumulated at the ice margin during the culmination of the advances. The successive moraines in any given area are thus supposed to mark the successive readvanced positions of the ice front. For this subject see specially the writings of F. B. Taylor, "Moraines of Recession and Their Significance in Glacial Theory" [Jour. Geol. 1897. 5:421-66].

2 The description of these glacial river channels will be found in another bulletin of the State Museum, under the title, "Glacial Drainage between Batavia and Syracuse."

Plate 31

Drumlin profiles blending in smooth horizon line. Looking southwest from 1¼ miles southwest of Wayne Center. At least 12 drumlins in the view

Plate 32

Ridge drumlins 4 miles southeast of Clyde. Looking northwest from north and south road, 1 mile north of county line. Land of W. H. Lawrence. Three ridges lie in the background

Plate 33

Large and small ridge drumlins, 1 mile east of Lyons. Looking southwest. Land of George Warucke. Two minor ridges, in middle view, lying between two major ridges

in such case) but a belt further iceward, the rivers truncating the thinner border of the ice sheet.

Moraine belts like the Auburn and Seneca Falls moraine represent only the superglacial and higher englacial drift, carried to and passively dropped at the extreme margin, while, pari passu, the drumlins were forming beneath the ice in the rear of the moraine, from the subglacial (and perhaps the lower englacial) drift.

When recession of the ice front again occurred, either by increased melting or by diminished ice movement, the superior drift was quietly lowered on the drumlin territory, falling chiefly in the hollows between them. Not infrequently we find a patch of irregular surface among the drumlins which can readily be discriminated and mapped as moraine, and rarely this may obscure the half buried drumlins [*see* p. 412] as in the Junius kame area. Sometimes the volume of moraine drift increases to the north and is so distributed as to give a decided morainal surface among the northern drumlins, as in the Walworth district [pl. 15]; or else the next succeeding moraine on the north laps on to the north edge of the drumlin belt, as in the Oswego district [pl. 6].

At the termination of heavy lines of glacial drainage, during both the active and the stagnant episodes, heavy deposits of water-laid drift (kame moraines) accumulated, as the Junius, Victor, Irondequoit valley, Mendon, and other kame areas.

Theoretically the moraines should be weak where the drift was left in drumlin form, and the facts seem in accord. In the stretch from Batavia to Syracuse the moraine belts are weak, though a few kame areas are strong.

Special features

Syracuse island masses. These remarkable groups are partly shown in plates 9 and 10 and are fully shown on the Syracuse and Baldwinsville sheets. They are partly bounded by river channels of the latest glacial drainage cut in Salina shales. North of Warners [pl. 9] is an example of such drumlin massing not surrounded by river valleys. In the more striking of these groups there is a cumulation or increase of hight toward the center which is a peculiar feature. If these drumlin masses have a core of rock reaching above the Salina shales, which form their base up to 500 feet or more, it has not been found, though it is not improbable for the more northerly groups.

The isolation of these groups can not be entirely due to channeling by the later drainage because the drumlins which cap the island-like rock masses are not themselves eroded, but lie wholly above the plane of the river work. It appears as if the ice rubbing did not touch the lower levels but was confined to higher planes. The forms do not seem explicable on the postulate of a single ice invasion with one episode of correlating ice border drainage. The relation of the drumlins to the erosion, and the character and direction of the stream courses [pl. 9, 10] suggest a complicated history. We have here only one of several groups of phenomena which argue for more than one ice epoch with their correlated stream work.

Montezuma island groups. Plate 12 shows the largest of several groups of drumlins which rise out of the marshes that occupy the low ground north of Cayuga lake. These are not conical or cumulative masses like those described above, but isolated groups, of irregular forms and sizes, even down to single drumlins. In the Montezuma district these groups or individuals rise out of the broad marshes as if half drowned. A few small knolls are mapped about the borders of the marshes, like the summits of nearly buried drumlins, but it does not seem likely that the absence of drumlins over wide tracts could be due to entire burial of drumlins under lake and vegetal accumulations. More likely the marshes are only the low areas similar to others at higher levels that are destitute of drumlins. This leads to the next topic.

Nondrumlin areas: open spaces. The broad swamp tracts, like the Montezuma marshes, belong in this category as well as more elevated and drier areas. An example of the latter lies north of Clyde, where a large tract in the center of the Clyde quadrangle shows white on the topographic sheet. The east edge of this tract is shown in plate 3, figure 3. This surface was under Iroquois waters but the lack of drumlins is certainly not due to their destruction. Evidently they were not formed in this tract. The reason is obscure, since the area is irregular in shape with scattering drumlins on all meridians and close set on the west, east and south. This absence of drumlins over considerable tracts in the midst of heavy development is more difficult of explanation than the formation of the drumlins themselves

These puzzling features lie in the region of deep drift filling of ancient valleys, the northward continuation of those now holding

Plate 34

Eroded north end of drumlin, 2 miles southeast of Clyde. Looking west of south. Erie canal and railroads in middle view

Plate 35

Abrupt north ends of drumlins, $1\frac{1}{2}$ miles southeast of Clyde. Looking southeast

North end of drumlin, 1/3 mile west of Savannah. Looking south from New York Central Railroad. The end is eroded obliquely by Iroquois waves

the finger lakes, and chiefly in the north and south depression of Sodus bay and Cayuga lake. The nondrumlin spaces can not be regarded as having been occupied by stagnant ice during the drumlin-shaping episode since they are surrounded by drumlins, and are comparatively free from moraine. They can not represent areas of ice movement too vigorous for drumlin accretion or shaping as the ice along the line of flow must have had a practical equality of motion. There is no reason for supposing that there was any lack of drift, since an immense quantity is piled in drumlins immediately southward. The location and distribution of the spaces, as well as the drumlins themselves, are such as to oppose the idea that the drumlins represent an original morainal distribution of earlier drift. We have to recognize the probable equality of the drumlin and nondrumlin loci in the elements of depth and pressure of the ice, in its impact and velocity of motion and in its burden of drift

The following suggestions are offered toward the explanation of these puzzling features. In the region of deep valley filling it is possible that some depressions were below the average level and consequently below the plane of the more vigorous thrustal motion, and it is conceivable that a plane of shearing might have been established above the depressions. Shearing once established would probably be unfavorable to the initiation of drumlins, as the drumlins imply some degree of local drag in the bottom ice during the time of accretion or shaping of the forms. The lowest of the open spaces have been partly filled with lake silts and stream detritus and vegetal accumulation, and some are still partly under water, as the Montezuma marshes; but the spaces north of Clyde do not appear to have been leveled by postglacial agents. The existence of well developed drumlins within or on the borders of open spaces might be due to accretion on existing obstructions, while the shearing tendency discouraged initiation of new masses.

A second suggestion is based on the idea of a complex glacial history. An earlier ice invasion may have localized and heaped the drift in part, while the interglacial stream work carved broad channels through the area, which the latest ice work has not wholly obscured.

Channels among the drumlins. These are connected with or blend into the open spaces discussed above and are part of the same problem. They are specially developed between Fairport and

Lyons; between Montezuma and Syracuse; and along the Seneca river. Those with direct east and west course were occupied by the latest ice border drainage but apparently were not wholly produced by it. These features appear on the Macedon, Palmyra, Weedsport and Syracuse sheets, and a suggestion of them is shown in plates 9–12. The channels all lie in Salina shales and possibly they have some genetic relation to the erodible nature of the rocks.

The existence and location of these low, continuous passages are strikingly emphasized by the remarkable windings of even the larger streams, Seneca river for example. The northward turns which this wayward stream makes east of Savannah, and more strikingly from Cross lake (an open tract) around by Baldwinsville and south to near Onondaga lake, must have been found open or the stream would have taken the direct eastward passages that are almost as low today even without any postglacial erosion. A smaller illustration is found in the case of Ganargua creek east of Palmyra, where it deserts the open glacial stream course and wilfully turns north around by East Palmyra in a constricted and uninviting pass, and repeats the act with less excuse northeast of Newark.

One suggestion for these open passages, which were certainly left open by the ice removal and were not cut by postglacial erosion, is that they were made by subglacial drainage, either under free flow or under hydraulic pressure. This seems reasonable for south-leading passages like those northeast of Clyde, and even for north-leading channels of gentle grade, like the valley of Dead creek in plate 10; but it is not satisfactory for the east and west passes which were transverse to the ice movement.

Another suggestion is that the passes were cut by glacial drainage of an earlier ice sheet, with modification by the subsequent interglacial erosion. It seems probable that the complex history of the region may involve such episodes and activities; or that perhaps the oscillations of the last (Wisconsin) ice sheet were sufficiently extensive to produce the phenomena. The difficulty under this theory is to explain why the drumlin-making work of the ice did not rub the channels full of drift. This difficulty is of the same kind, however, as the absence of drumlins over interdrumlin tracts. In the case of the deep channels around the Syracuse island masses it might be suggested that possibly during the latest stage the channels were occupied by stagnant ice over which the drumlin-forming layers

Plate 37

Eroded drumlin, west edge of Savannah. Looking south from New York Central Railroad. The north end cut obliquely by Iroquois waves

Plate 38

Drumlin eroded at south end by Iroquois waves. 2 miles west of Savannah; looking northeast. Note the house in the orchard, and the abrupt notch in the drumlin. The crest of the drumlin was originally at about the top of the barns. Compare plate 39

Plate 39

South ends of drumlins 2 miles west of Savannah. End view of drumlin shown in plate 33. Looking north from tracks of New York Central Railroad

moved or slid by shearing; but this could hardly apply to the Clyde and Montezuma districts, where the drumlin forms lie at the lowest levels.

A modification of the subglacial drainage theory offers some help. It seems probable that the last stage of the glacier in this region left an extensive border tract of stagnant ice, and that unequal melting due to a variety of causes produced detached blocks or tracts of ice around or among which the copious glacial waters excavated many channels. The subglacial drainage combined with the later inter-ice block drainage may largely account for the peculiar features. In this connection it must be understood that the attitude and elevation of the land surface of the region has changed to some extent since the features were made; and that the lakes and sluggish waters, aided by organic growths, have partially filled the low grounds.

Summary

Age of the drumlins. The form and relations of the drumlins in the Pulaski district, due to the change of direction in the ice flow proves that they were shaped during the latest phase of the ice work in that locality, and not during any earlier stage. The same conclusion is reached by the theoretical considerations and enforced by the facts of observation for the entire drumlin area.

The peculiar distribution of the drumlins and their orientation prove that they were shaped by the spreading flow of the semistagnant ice mass reposing in the Ontario basin. The correlation of moraines and of ice border drainage channels with the attenuated edge of the main belt of drumlins indicates that the drumlins were formed beneath the border of the ice sheet. This correlation of the drumlin shaping with the latest work of the ice in the drumlin region has been noted in other drumlin areas, as Wisconsin, Massachusetts, Ireland and Germany. The fact seems to be sufficiently established that the alinement and shaping of the drumlins was given under the waning border of the ice sheet, at least in the case of the continental glaciers.

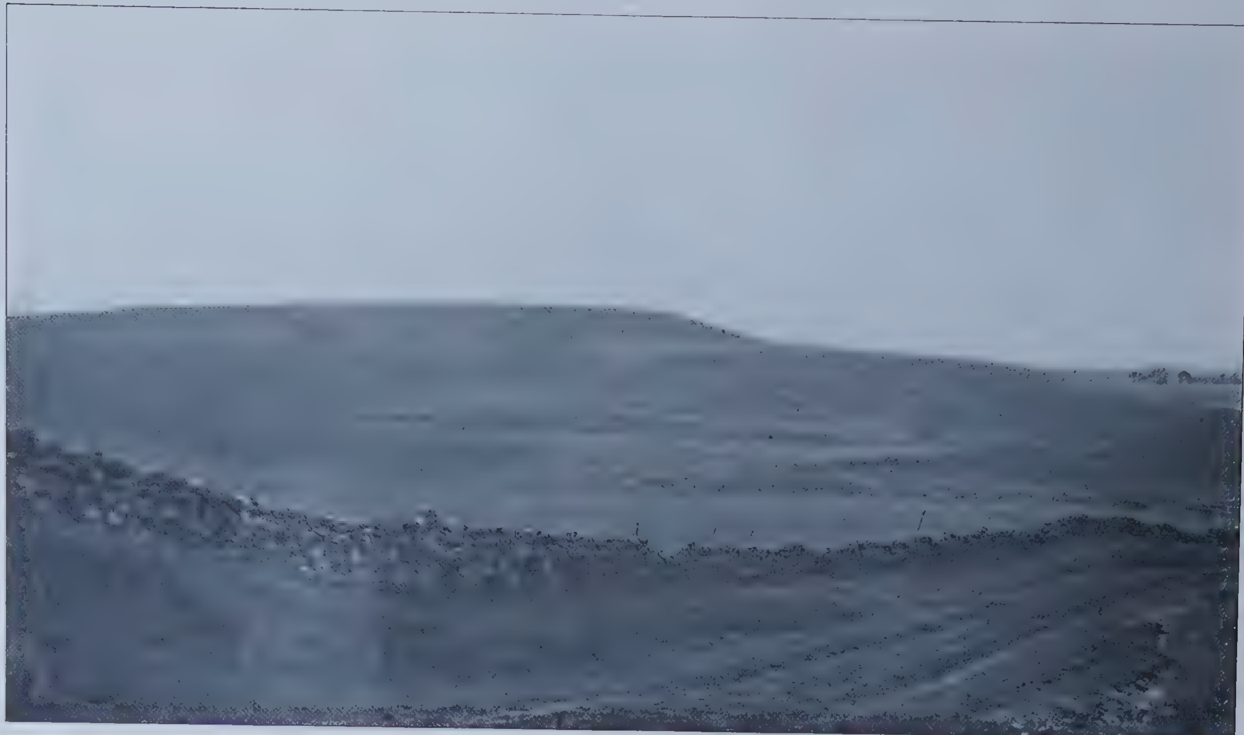
Thrust motion of the ground contact ice. Drumlins are shaped by the sliding movement of the lowest ice, that in contact with the land surface. This fact implies that the whole thickness of the ice sheet participated in the motion. Such motion was not due to gravitational stress on the ice mass over the drumlin area, because the

general slope of the drumlin area is up hill, but was produced by an effective thrust on the marginal ice by the pressure of the rearward mass. As the ice sheet thinned by ablation there came a time when the drift-loaded ice in contact with the ground was subjected to less vertical pressure and to relatively greater horizontal pressure by the deep ice in the rear, and was *pushed forward, bodily*. In this fact is believed to lie the key to drumlin formation.

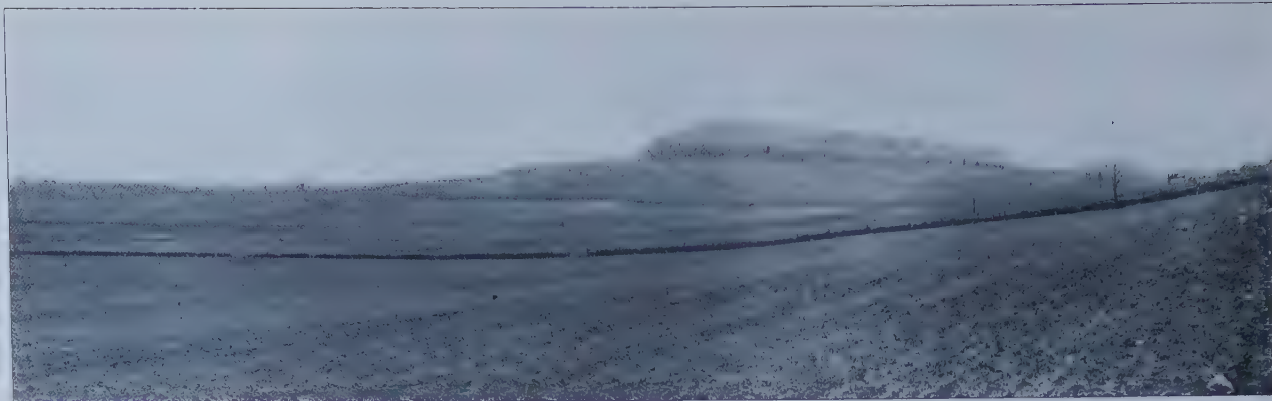
It does not follow that drumlins must always have been formed where the bottom ice had a sliding motion, as several other conditions are probably requisite, but it seems quite certain that long-continued and vigorous horizontal thrust is the prime necessity. Such thrustal movement would be effective only where a border of the ice sheet was backed by a thick or vigorously pushing rearward mass. The combination of conditions requisite for effective thrust movement over a belt of country and for the considerable time necessary to build up the drumlins may be rare. It does not seem so strange that drumlins are uncommon features of the drift when we add to the requisite dynamic factors mentioned above the several others which are doubtless directly concerned with the drumlin formation.

As a working hypothesis it may be assumed that wherever the ground contact ice had a vigorous movement of some duration it should be indicated by the molding of the ground surface, specially where that surface is comparatively smooth and composed of drift or soft rocks. The form and degree of the ice molding would vary according to the strength and adjustment of the several factors. An application of this idea can be made to the region under present study.

Well marked drumlins are not found on the high ground east of Seneca lake, and are wanting on the low ground east of Syracuse. The explanation seems to lie in the relationship of the larger topography to the movement of the ice sheet. When the glacier was deep over the Finger lakes region the bottom of the ice in the drumlin area was probably quiescent and served as the bridge over which the upper ice moved by gravity; the repose of the lower ice probably being due to the opposing land slope and to the large volume of drift which the ice had incorporated. Over the nearly level area north of the Finger lakes the waning of the ice sheet finally subjected the ground-contact ice to a vigorous and long-continued horizontal thrust with consequent sliding motion. But in the adjacent



Superposed drumlin. Cushman hill, 2½ miles northwest of Scottsville. Looking south of west



Superposed drumlin. Hosmer hill, 4 miles northwest of Scottsville.
Upper, distant view, looking southeast; top drumlin in forest. Lower, near view, looking west of north

Plate 42

Superposed drumlin. Martin hill 1 mile east of West Rush. Looking south of east

district of low ground northeast and east of Syracuse (over Oneida lake, Canastota, Oneida and eastward) we have an illustration of nonmotion of the ground-contact ice. The almost bare hills of soft Vernon shales in the region of Canastota have not been subjected to the rubbing action of the ice from any direction. In form these clay hills closely resemble moraine drift, and with their slight veneer of glacial rubbish would at first be mistaken for moraine by even the experienced geologist. This surface would have been sensitive to any ice movement, the absence of which is explained as follows: While the ice sheet was thick the flow was from the northward and the ground-contact ice in this district, lying in the broad depression between the Adirondack massive on the north and the high plateau on the south, was quiescent. With the waning of the ice sheet it disappeared from the high ground to the north so that the stagnant mass resting on the Canastota-Oneida district was not subjected to any push from the northward. During the closing or drumlin-making phase of the ice work in the Ontario basin the radially spreading ice of the Ontarian mass did not reach this district. In brief, the ground-contact ice over the Canastota-Oneida district, although occupying a low tract on the edge of the drumlin area, did not at any time receive horizontal impulse but was deserted and allowed to quietly melt away, or perhaps to be lifted and rafted off in the glacial lake waters which fronted the glacier. The extreme reach of the drumlin-forming activity in the Syracuse district was in the form of a tongue or wedge of moving ice which was thrust southeastward along the Onondaga lake depression and over the site of Syracuse, ending a few miles southeast of the city; and affecting only the higher ground, or the summits of the island masses.

Origin. It is certain that the New York drumlins were constructed or built up by a plastering-on process. The ice did not drop its drift burden in the depressions or low places but plastered it on the obstructions. The plastic and adhesive character of the shale-derived drift of central New York is probably one factor accounting for the great number, hight and shape of the drumlins of that district.

The rocdrumlins, or shale hills with the peculiar drumlin form, being shaped by a moderate amount of erosion of the soft rock might suggest, at first thought, that erosion was the main factor in drumlin formation. Possibly it may be in some regions; but vig-

orous abrasion of hard rocks would scarcely be consistent with drumlins in the same locality.

The building of drumlins by the plastering process was coincident with a rubbing off and shaping effect. As masses or hills the drumlins were produced by accretion of the drift, but their peculiar form is due to the erosional factor. The whole process may be compared to the work of the sculptor on a clay model: a plastering on and rubbing away. The accretion was due to the greater friction between clay and clay than between the clay and ice. The hills of accretionary drift resisted the ice impact and rasping effect just as did the hills of shale. The form possessed by both classes of hills is that which opposed successful resistance to the ice erosion, and the least resistance to the ice movement.

Dynamics. It seems evident that in the typical drumlin area the ice did not move as a solid mass or even in wide sections, for such motion should produce a planing or leveling effect, such as is illustrated in the Niagara-Genesee prairie [pl. 19]. The drumlins are proof of a plastic flow or yielding of the ice; while the long, straight ridges suggest that the ice was pushed in comparatively rigid bolts or prisms that wavered and shifted.

In the balancing and adjustment of the several dynamic factors in the drift-burdened ice the two opposing forces of rigidity and plasticity seem to be the most important. The amassing of the drift into drumlin form, or at least the nonremoval of the hills, implies that the depth of ice and the vertical pressure were so moderate as to allow the plastic ice to override and adapt itself to the hills, while at the same time the whole sheet of ice was sufficiently rigid to move under horizontal thrust.

Judging from the facts and theoretic mechanics noted above it would seem that the drumlins represent the short lines of temporarily diminished pressure and of lagging flow. These lines of variable pressure and motion, though close set in the dominant drumlin area, must have been discontinuous, short and constantly shifting. Drumlins could not have been determined, as regards location at least, by external influences, as atmospheric agencies above or topographic and geologic features beneath, but must have been produced by the interaction of the mechanical factors resident within the ice itself, the latter moving as a plastic solid. Their initiation may have been

Plate 43

Erosion cliff in drumlin; Lake Ontario shore. "Chimney bluff," 2 miles northeast of Sodus bay. Looking southeast

Plate 44

Foliated drumlin structure. "Lake Bluff," Sodus bay, shore of Lake Ontario. Looking southeast

Plate 45

Foliated drumlin structure. "Blind Bay bluff," shore of Lake Ontario, 5 miles northeast of Sodus bay. Looking south

due to some obstruction beneath the ice or to a local amassing of drift by the ice itself.

Drumlin forms. The breadth of the Oakfield-Scottsville-Palmyra-Syracuse drumlin belt or series, which is supposedly a unit in time of formation, is about 20 miles wide in the central part. The eastern Ontario series has about the same width on the Fulton sheet.

If the northern and broader drumlins in each belt were mostly built contemporaneously with the southern attenuated forms, as seems most probable, then we may assign a few of the conditions that were responsible for the different forms.

The northern, broader and more widely separated drumlins, such as those at Sodus [pl. 4], were certainly under greater vertical pressure on account of the greater depth of the ice. This might have given greater potential plasticity, though the effective plasticity and the differential movement might have been less than in the central part of the belt. On the other hand the attenuated drumlins [pl. 13] under the thinner ice near the border of the sheet would be subject to less vertical pressure. Here the ice had less frontal resistance and therefore freer movement; it was less burdened with drift, having already built the drumlins in the rear; and probably it had less effective plasticity and less differential movement. In other words, the attenuated, border forms of the drumlin belt were formed beneath ice moving with relatively greater freedom, greater relative rigidity, and with more uniformity and continuity.

The culmination of the drumlin-making process seems to have been in the middle of the belt, where the several dynamic factors were well balanced and were working together at the maximum of efficiency. There the drift was abundant and plastic; the rigidity and the plasticity of the ice were active but well balanced; and the differential flow was at its maximum, that is to say, the ice was not moving in long, rigid bolts or wide masses but in short and wavering prisms.

The very long and flat ridges characteristic of the Niagara-Genesee prairie [pl. 18, 19] seem to be the product of steady and long-continued movement of thicker and more rigid ice than that which built the shorter, steeper and crowded drumlins in the middle of the State. The ice probably had less burden of drift, less differential flow and less effective plasticity. The effect was similar to the production of

the small, linear forms on the attenuated drumlin border in the Waterloo-Seneca Falls district, but the work was on a much larger scale. The direction of the drift molding in the western district, it should be noted, is that of the prevailing direction of the continental glacier over the region.

Depth of the drumlin-making ice. We have no conclusive facts on this topic but some suggestive data. The relationship of the Waterloo-Seneca Falls moraine, and of the ice-border drainage channels on the west, to the south edge of the main drumlin series seems to locate definitely the edge of the ice sheet during that episode. North of the Finger lakes region the receding ice front was continuously bathed by glacial lake waters, and the moraines were laid down under water. The moraine above named seems to correlate with certain deltas and outlet channels to the east. If the correlation is correct the water in which the moraine was deposited had a surface altitude, present elevation, of about 900 feet. The depth of water at the ice front was therefore about 400 feet, since the moraine tract lies at about 500 feet.

As the moraine is weak, largely because the drift load had been incorporated into the drumlins in the rear, we may assume that the ice was not heavily anchored in the lake water by its load of rock rubbish. In order to retain its place under the buoyancy of the waters it must have been at least 450 feet thick, or 50 feet above the water. Taking this as the minimum depth of ice at the glacier margin and assuming a surface slope of 30 feet to the mile, the elevation of the surface of the glacier over Clyde, 12 miles north of the moraine, would be ($950+30 \times 12$) about 1310 feet. Since the general base of the Clyde drumlins is about 400 feet elevation the depth of ice in the center of the drumlin belt was about 900 feet. The drumlins are less than 200 feet high, which gives a depth over their tops of more than 700 feet of ice. This is merely suggestive.

Complex history. It is very likely that there are undiscovered and unsuspected elements in the Pleistocene history of central-western New York, and that it is much more complicated than it now appears. Probably there has been more than one epoch of ice invasion and retreat along with heavy erosion by glacial and non-glacial waters. As we see the drumlins today they represent in their forms, in each series, the latest ice work; but it is quite possible that some of them were related to an earlier ice sheet.

Plate 46

Foliated drumlin structure. "Nigger hill," 4 miles west of Sodus point, shore of Lake Ontario. Looking southwest

Plate 47

Drumlins of Ireland

The remarkable series of drumlins described by Kinahan and Close[1] have a special interest in this study, as they are the type forms, produced by local glaciation in a far distant land, and are strikingly similar in essential features to our New York forms.

The distribution of the principal group of the Irish drumlins is shown on plate 47 which is a copy, in reduced size, of a portion (upper right corner) of the original map by the Irish authors. The direction of flow of the ice current that produced this group of drumlins was toward the north, and spreading specially to the west, toward Clew bay; but in other districts the few drumlins have other directions, corresponding to the radial flow of the ice away from the local center of accumulation. The arrangement of the drumlins in curving lines of the ice flowage is very striking, and not easily explained except by the constructional theory of their genesis.

The drumlins are described as occurring only on low ground, and even forming islands and shoals in the sea (Clew bay). Their absence from some parts of the low plain is noted as a feature not understood.

The up stream ends of the drumlins (with reference to the ice currents) are noted as the blunt ends, although this is not stated as a constant feature, since the hills have suffered some erosion by marine submergence.

The "parallel shaping" of the general ground surface in the drumlin district was observed.

The extreme hight of the drumlins is given as 180 feet, in striking accordance with the New York forms. Another important observation is the "observable uniformity in size in the same neighborhood." Concerning length it is noted that several of the drumlins are 2 miles long; and that the mean length is not less than ½ mile.

With reference to the composition the authors say that the drumlins "consist of stiff, unstratified boulder clay, containing well blunted and scratched stones and blocks." "They have been

1 Kinahan, G. H. & Close, H. M. General Glaciation of Iar-Connaught and its Neighborhood, in the Counties of Galway and Mayo. With map. Dublin 1872.

For the favor of seeing this somewhat rare pamphlet and using its matter and map the writer is indebted to Mr F. B. Taylor.

unquestionably formed by some operation different from, and antecedent to, that which produced the water-arranged gravels and eskers. Deposits of water-formed gravel, etc., clearly of later date, often occur in the lower ground between the drumlins, and even banked up against them."

The authors apparently regarded their drumlins as constructional forms and did not regard the matter as needing discussion, since they refer to the origin of the drumlins only incidentally, as follows:

"No agent which can not do both kinds of work, rock-scoring and drumlin-heaping, can be proposed as having caused them" [p. 9].

". . . And it has formed the drumlins by an operation evidently similar to that by which a stream of water often makes longitudinal ridges of sand in its bed."

Bibliography

The following list of writings in English relating to drumlins is not exhaustive, and it is possible that some valuable references have been overlooked, specially of foreign authors. Numerous incidental references have been purposely omitted. Outside of English the literature seems scanty, but an important paper in German is noted on page 394.

Persons unfamiliar with the phenomena of drumlins might well begin the study by reading the paper by W. M. Davis that is given as his fourth title in the following list; and later the papers by Warren Upham for the years 1889, 1892 and 1893.

Barton, G. H. Bost. Soc. Nat. Hist. Proc. 1892. 26: 23–25.

——— Glacial Origin of Channels on Drumlins. Geol. Soc. Am. Bul. 1894. 6: 8–13.

Bonney, T. G. Ice-work, Past and Present. 1896. p. 116–19.

Chalmers, Robert. Geol. & Nat. Sur. Can. An. Rep't. n. s. 1888–89. p. 23 N.

Chamberlin, T. C. U. S. Geol. Sur. 3d An. Rep't. 1881–82. p. 306.

——— Geol. Wis. 1883. 1: 283.

——— Am. Ass'n Adv. Sci. Proc. 1886. 35: 204.

——— Horizon of Drumlin, Osar and Kame Formation. Jour. Geol. 1893. 1: 255–67, 521–24.

——— Am. Geol. 1893. 12: 176.

——— Geol. Soc. Am. Bul. 1895. 6: 216.

——— The Great Ice Age. Ed. 3. 1895. p. 743–45. (James Geikie)

——— **& Salisbury, R. D.** Geology. 1906. 3: 360.

Close, H. M. On the Glaciation of the Rocks near Dublin. Roy. Geol. Soc. Ireland. Jour. 1864. 1: 3.

——— Notes on the General Glaciation of Ireland. Roy. Geol. Soc. Ireland. Jour. 1866. 1: 207.

——— Roy. Geol. Soc. Ireland. Jour. 1877. 5: 49.

Dana, J. D. Am. Jour. Sci. 1883. ser. 3. 26: 357–61.

Davis, W. M. & Shaler, N. S. Illustrations of the Earth's Surface; Glaciers. 1881. Text describing plate 24.

——— Bost. Soc. Nat. Hist. Proc. 1883. 22: 34, 40–42.

——— Drumlins. Science. 1884. 4: 418–20.

——— The Distribution and Origin of Drumlins. Am. Jour. Sci. 1884. ser. 3. 28: 407–16.

——— Bost. Soc. Nat. Hist. Proc. 1893. 26: 17–23.

——— Physical Geography. 1898. p. 338.

Fairchild, H. L. Glacial Geology of Western New York. Geol. Mag. Lond. 1897. n. s. dec. 4. 4: 532.

——— Glacial Geology in America. Am. Ass'n Adv. Sci. Proc. 1898. 47: 257–90; Am. Geol. 1898. 22: 154–89; Am. Sci. Sup. 1898. no. 1183–85.

——— Elements of Geology. (LeConte) 1903. p. 71, 571.

——— New York drumlins (abstract). Geol. Soc. Am. Bul. 1905. 16: 576.

——— Drumlin Structure and Origin. Geol. Soc. Am. Bul. 1907. 17: 702-7.

Geikie, James. Geol. Soc. Glasgow. Trans. 1867. 3: 61.

——— The Great Ice Age. 1895. Ed. 3. p. 17, 81, 411, 432, 743–45. (T. C. Chamberlin)

——— Earth Sculpture. 1898. p. 234–35, 245, 378.

Hall, James. Geol. N. Y.: Rep't on Fourth District. 1843. p. 341, 414–15.

Hall, *Sir* James. Roy. Soc. Edinburgh. Trans. 1815. 7: 169.

Harte, W. Roy. Geol. Soc. Ireland. Jour. 1867. 2: 30.

Hitchcock, C. H. Lenticular Hills of Glacial Drift. Bost. Soc. Nat. Hist. Proc. 1878. 19: 63–67.

——— Lenticular Hills. Am. Jour. Sci. 1884. III. 27: 72.

Johnson, Laurence. Parallel Drift Hills of Western New York. N. Y. Acad. Sci. An. 1883. 2: 249–66, pl. 18. N. Y. Acad. Sci. Trans. 1882. 1: 78–80.

Kinahan, G. H. & Close, H. M. General Glaciation of Iar-Connaught and its Neighborhood, in the Counties of Galway and Mayo. Map. Dublin 1872.

Leverett, Frank. Illinois Glacial Lobe. U. S. Geol. Sur. Monogr. 38. 1889. p. 73, 135.

——— Glacial Formations and Drainage Features of the Erie and Ohio Basins. U. S. Geol. Sur. Monogr. 41. 1902. p. 691–93, pl. III.

——— Mich. Acad. Sci. 6th An. Rep't. 1904. p. 102.

——— Drumlins in the Grand Traverse Region of Michigan. Geol. Soc. Am. Bul. 1905. 16: 577.

Lewis, H. C. Second Geol. Sur. Pa. Rep't Z. 1884. p. 28.

Lincoln, D. F. Glaciation in the Finger Lakes Region of New York. Am. Jour. Sci. 1892. III. 44: 290–301.

——— N. Y. State Mus. Rep't 48. 1894. 2: 69–71.

Marbut, C. F. & Woodworth, J. B. Clays about Boston. U. S. Geol. Sur. 17th An. Rep't. 1896. p. 995–98.

Matthew, G. F. Geol. & Nat. Hist. Sur. Can. Rep't of Prog. 1877–78. p. 12–14 EE.

Russell, I. C. Jour. Geol. 1895. 3: 831.

——— Glaciers of North America. 1897. p. 24–28.

——— Geol. Sur. Mich. 1904. p. 69–81.

——— Drumlin of Michigan. Geol. Soc. Am. Bul. 1907. 17: 707.

——— Drumlin Areas in Northern Michigan. Geol. Soc. Am. Bul. 1905. 16: 577–78.

Salisbury, R. D. Geol. Sur. N. J. An. Rep't 1891. p. 71–74.

——— Am. Geol. 1893. 12: 172.

——— Geol. Soc. Am. Bul. 1893. 4: 9.

——— Glacial Geology. Geol. Sur. N. J. 1902. 5: 103.

——— **& Chamberlin, T. C.** Geology. 1906. 3: 360.

Shaler, N. S. Bost. Soc. Nat. Hist. Proc. 1868. 11: 27.

——— On the Parallel Ridges of Glacial Drift in Eastern Massachusetts. Bost. Soc. Nat. Hist. Proc. 1871. 13: 196–204.

——— **& Davis, W. M.** Illustrations of the Earth's Surface: Glaciers. 1881. 4: 60–63.

——— U. S. Geol. Sur. 7th An. Rep't. 1886. p. 321–22.

——— U. S. Geol. Sur. 9th An. Rep't. 1888. p. 550–51.

Stone, G. H. Bost. Soc. Nat. Hist. Proc. 1881. 20: 434; Port. Soc. Nat. Hist. Proc. 1881. Mar. 11, Nov. 21.

Tarr, R. S. Origin of Drumlins. Am. Geol. 1894. 13: 393–407.

——— Physical Geography of New York State. 1902. p. 144–51.

——— New Physical Geography. 1904. p. 152–53.

Taylor, Frank B. Distribution of Drumlins and its Bearing on their Origin. Geol. Soc. Am. Bul. 1907. 17: 726.

Tyrrell, J. B. Geol. Sur. Can., An. Rep't. 1888–89. n. s. 4: 22 A.

——— Geol. Soc. Am. Bul. 1890. 1: 402.

——— Geol. Sur. Can. 1892. 6: 15 A.

——— Am. Geol. 1893. 11: 132, 175.

Upham, Warren. Geology of New Hampshire. 1878. 3: 285–309.

——— Glacial Deposits in New England. Am. Ass'n Adv. Sci. Proc. 1879. 28: 309–10.

——— Glacial Drift in Boston and Vicinity. Bost. Soc. Nat. Hist. Proc. 1879. 20: 220–34.

——— Marine Shells and Fragments of Shells in the Till near Boston. Bost. Soc. Nat. Hist. Proc. 1888. 24: 127–41; Am. Jour. Sci. 1889. ser. 3. 37: 359–72.

——— Structure of Drumlins. Bost. Soc. Nat. Hist. Proc. 1889. 24: 228–42.

——— Inequality of Distribution of the Englacial Drift. Geol. Soc. Am. Bul. 1891. 3: 134–48.
——— Criteria of Englacial and Subglacial Drift. Am. Geol. 1891. 3: 376–85.
——— Conditions of Accumulations of Drumlins. Am. Geol. 1892. 10: 339–62.
——— Geol. Soc. Am. Bul. 1892. 3: 140.
——— Origin of Drumlins. Bost. Soc. Nat. Hist. Proc. 1893. 26: 2–17.
——— Madison Type of Drumlins. Am. Geol. 1894. 14: 69–83.
——— Drumlin Accumulation. Am. Geol. 1895. 15: 194–95.
——— Drumlins and Marginal Moraines of Ice Sheets. Geol. Soc. Am. Bul. 1896. 7: 17–30.
——— Drumlins Contained or Lying on Modified Drifts. Am. Geol. 1897. 20: 383–87.
——— Valley Moraines and Drumlins in the English Lake District. Am. Geol. 1898. 21: 165–70.
——— Drumlins in Glasgow. Am. Geol. 1898. 21: 235–43.
Wright, G. F. Bost. Soc. Nat. Hist. Proc. 1876. 19: 58.
——— Bost. Soc. Nat. Hist. Proc. 1881. 20: 217.
——— Ice Age in North America. Ed. 4. 1891. p. 251–67.
——— Man and the Glacial Period. 1893. p. 75.

INDEX

Published monthly by the
New York State Education Department
BULLETIN 413 SEPTEMBER 1907

New York State Museum

JOHN M. CLARKE, Director

Bulletin 115

GEOLOGY 14

GEOLOGY OF THE LONG LAKE QUADRANGLE

BY

H. P. CUSHING

New York State Education Department
Science Division, October 19, 1906

Hon. Andrew S. Draper LL.D.
Commissioner of Education

SIR: I beg to communicate herewith, for publication as a bulletin of the State Museum, an account of the geology of the Adirondack region known as the Long Lake quadrangle accompanied by a geological map on the scale of 1 mile to the inch, both of which have been prepared by Prof. H. P. Cushing.

Very respectfully

JOHN M. CLARKE
Director

Approved for publication this 20th day of October 1906

A. S. Draper
Commissioner of Education

New York State Education Department

New York State Museum

John M. Clarke, Director

Bulletin 115

GEOLOGY 14

GEOLOGY OF THE LONG LAKE QUADRANGLE

BY

H. P. CUSHING

ACKNOWLEDGMENT

A portion of the field work, on which the following report is based, was done in conjunction with the topographers of the United States Geological Survey, while they were mapping the district. In country of this kind, where accurate location of outcrops is by no means the least of the difficulties under which the geologist labors, combined work of the sort is highly advantageous, since the topographer locates the geologist's outcrops for him, and that with a high degree of accuracy. The arrangement was highly advantageous to the State Museum, as well as to the writer, and he wishes to express his hearty acknowledgments to Mr H. M. Wilson, whose permission made the arrangement possible, and to Mr J. M. Whitman jr, and Mr A. P. Meade jr, for a vast number of courtesies, and a very helpful and pleasant field season.

SITUATION AND CHARACTER

The Long Lake quadrangle comprises that part of the Adirondack region lying between parallels 44° and 44° 15′ n. latitude, and meridians 74° 15′ and 74° 30′ w. longitude, its area being slightly over 218 square miles. If the Adirondack region is understood to comprise the entire district of the north woods, then this quadrangle lies about midway, or in the heart of the district. It is however situated on the western border of the more rugged portion of the area, that included in the Adirondack mountains proper.

The quadrangle is noteworthy for the variety of topography presented. The main axis of elevation of the region crosses it,

and its eastern border hugs the western edge of the high Adirondacks, the Santanoni quadrangle, just east, being one of the loftiest, most rugged, and most unsettled of the whole region. The southern border of the depressed "lake belt" shows well in the northern part of the quadrangle. The northern and southern halves of the Adirondack region are of somewhat different topographic character, great igneous rock masses predominating in the former, and gneisses of various kinds in the latter, and the line of division between the two crosses the quadrangle from east to west about midway. The differences however are not as prominently brought out in the sketching, as they appear in the field.

The Raquette, one of the greatest of the Adirondack streams, runs across the quadrangle, Long lake being merely a somewhat widened and perhaps deepened portion of the stream, which enters it at one end and leaves it at the other. The great reach from Raquette falls to Piercefield, not far beyond the map limits to the west, is the longest possessed by any Adirondack stream. The rapids at Raquette falls are the only interruption to navigation on the river which are found within the map limits.

The quadrangle is also nicely illustrative of the number and variety of the Adirondack lakes and ponds, 57 of which are found, in whole or in part, within its borders. Three of the larger lakes of the region, Big Tupper, Upper Saranac and Long lakes, are shown in part, somewhat over half the length, and all the wider part of Long lake being included. Of those wholly within the area of the map, Follensby pond is the largest, followed in order by Catlin lake, and Big Simons and Jenkins ponds, with thence a regular downward gradation to ponds so small as to make little showing on a map of this scale. In elevation of mean water level they range from the 1534 feet of Big Tupper and Big Simons, to the 2050 feet of Seward pond. Some of them are rock bound, in whole or part, with frequent rock islands; others have low shores of morainic material or of sand. Many of these latter are exceedingly shallow and are being rapidly converted into marshes. The extent of this conversion is well brought out on the map in several instances, as in the case of Pickwacket pond, in the extreme southeast portion of the quadrangle, and of Pickerel pond, 2 miles south of east of Axton. The Tupper Lake reservoir is simply a dredged out portion of what was a nearly marsh-filled lake basin.

With its frequent lakes, the long reach of the Raquette river

with its bordering swamps and cut-off oxbows, the broad belt of lowland separating the highlands of the north from those of the south part of the quadrangle, and the difference in character of those two highland areas, the quadrangle shows a diversity of topography rather unusual, even for an Adirondack map sheet.

Practically the entire area was forest covered until recently, and most of it is yet thus covered, though with a sadly changed forest. The rapid growth of the village of Tupper Lake, especially as a lumber center, has resulted in a steady increase in the amount of cleared land in its vicinity, and within the past 15 years the removal of the timber from the district has been rapid. The ordinary wasteful lumbering of the conifers (and much of the lumbering in the district has been of that type) is bad enough. But in addition a vast amount of small wood for paper pulp has recently been cut, and also much hard wood, so that there is now a wide area in the northern part of the quadrangle and thence northward for many miles, which has been practically deforested, and through which the great forest fires of May 1904 ran widely. Here as elsewhere, the Adirondack forest is disappearing, and much of it disappearing in such wise that reforestation will be a difficult, if not impossible matter.

GENERAL GEOLOGY

With the exception of the very recent, unconsolidated surface deposits, all the rocks found within the limits of the quadrangle are of Precambric age, or belong to the oldest known, great rock group. The length of that part of the earth's history which these rocks record is not known, either absolutely or relatively, but it is known that the lapse of time involved is exceedingly great, and it is quite probable that 50% or more of the entire geologic history of the earth is included. Furthermore most of the Adirondack rocks are of early Precambric age, or were formed during the first half of this long time interval. They are hence to be classed as among the earliest of the known rocks of the earth.

There are at least four great groups of these Precambric rocks, and their relations to one another are, for the most part, known. Unquestionably these groups are more or less capable of minor subdivision, but comparatively slight progress has yet been made in this direction. The study and interpretation of the history which these rocks imperfectly record is a matter of extreme difficulty, because the rocks have been profoundly modified, both

texturally and structurally, by action of great compressive forces, so much so that many of them have lost all trace of their original character. These four groups are

1 A series of old sedimentary rocks, the Grenville series, much involved with igneous rocks some of which seem of approximately the same age.

2 A series of gneisses which seem to be mainly or wholly of igneous origin, which may be, in part, older than the Grenville rocks, though no certain evidence of this has yet been forthcoming in the Adirondack region. If there are in the region any exposed rocks more ancient than the Grenville rocks, they are here.

3 A series of igneous rocks, usually in great masses (batholites), which are demonstrably younger than both the preceding, and which are not so profoundly changed in character, retaining often traces of their original textures and structures.

4 A series of very much younger igneous rocks which have undergone little change since their intrusion.

Rocks belonging to all four of these groups are found within the area of the Long Lake quadrangle, and all but the last have an extensive representation, the quadrangle being rather unusual in this respect.

Grenville series. Here are classed certain well banded gneisses and schists, some of them very quartzose and grading into quartzites, with bands of varying thickness of coarsely crystalline limestone. They are believed to be old water-deposited rocks, ancient sheets of sand, mud and calcareous mud deposited on the floor of some large body of shallow water, in all probability the sea. There is apparently a great thickness of these rocks, but neither their base nor summit is known, and they are so disturbed, and usually so poorly exposed that our ideas concerning their thickness are of the vaguest. They must have been deposited upon a floor of older rocks, but we are at present ignorant as to what these rocks were, and whether or not they are anywhere exposed in the district.

Because of the thickness and the frequent changes in the character of the deposit it is certain that the deposition of these rocks took a long time, pointing to a protracted submergence of the area at this early day, with frequent relative oscillations of the land and water levels. The close association of igneous rocks with them, some at least of which seem only found in this association, is thought to point to closely contemporaneous igneous action on a large scale.

Doubtful gneisses. Here are classed other rocks, differing from the preceding in that they seem to be wholly of igneous origin. They have been equally, if not more, changed from their original condition than have the rocks of the preceding group, and all traces of their original characters have disappeared. Similar rocks, in general not to be distinguished from them, occur associated with the sediments, where they are clearly as young, or younger than they are. So these may represent great masses of such rocks, massed in such amount as to have wholly displaced the sediments. On the other hand they may be, in part, older and represent the rocks of the floor on which the sediments were deposited. The question is, as yet, undecided; the former is the more probable.

Great igneous intrusions. The rocks of the two preceding series at present found in the district constitute only a fragmentary remnant of those formed at this early time. They have suffered large loss from above by surface wear, slow but long continued. They have likely also suffered loss from beneath owing to the attack of masses of igneous rocks which were working their way upward. Prior to the appearance of these intrusions the older rocks seem to have suffered compression and as a result to have been much changed in character. At the time of compression they must have been buried under a considerable load of overlying rock, the great masses of the intrusions solidified under large load, and both are now at the surface because of the removal of this overlying rock during long ages of surface erosion. The intrusive rocks invaded the entire district, but Essex and southern Franklin counties felt the full force of the invasion, these igneous rocks forming most of the present surface there, while elsewhere they are not as prominent.

These igneous rocks may be grouped into four great classes, anorthosites, syenites, granites and gabbros, all no doubt derived from some great parent molten mass beneath by some process of differentiation. The anorthosite intrusion was the first and bulkiest, forms the heart of the igneous district, and was followed by smaller and more scattered intrusions of syenite, of granite and of gabbro.

These rocks have also been profoundly modified by the action of great compressive forces, while deeply buried, but are not so thoroughly changed in character as the earlier rocks, retaining many traces of their original structures.

Following this time of igneous intrusion the region seems to have been a land area for long ages and to have undergone a prodigious

amount of surface wear during the interval. The thickness of rock removed is purely conjectural but must have been large, several thousand feet at least.

Later igneous rocks. Toward the close of this long erosion period came another time of igneous activity in the region, molten rock ascending toward the surface, and utilizing a system of east-west fissures for its ascent. Such lava-filled fissures are known as dikes, and such dikes are very numerous in the northeastern Adirondack region, though rather uncommon in the district under consideration. There was likely volcanic action at the surface, but this can only be conjectured since no known vestige of that surface now remains, all having been since worn away. The source of the material is equally conjectural, though quite likely the same as that whence the great intrusions sprang. At the present surface we see only the old, lava-filled channels of ascent.

Erosion still continuing after the close of the igneous activity, the surface was still further lowered, but by an amount to be measured in hundreds rather than thousands of feet, the character of the dike rocks clearly indicating that they solidified at no great depth.

Paleozoic submergence. Around the borders of the Adirondack region we find, resting upon the Precambric rocks, a series of sandstones, limestones and shales of early Paleozoic age, the Potsdam sandstone of Cambric age beneath, and above in order the Beekmantown dolomites and limestone, the Chazy, Lowville, Black River and Trenton limestones, and the Utica shale, all of Lower Siluric age. In the heart of the region such rocks are wholly absent, save as scattered glacial boulders. Yet nothing is more certain than that they formerly extended over much of, if not over the entire, Adirondacks. When the submergence beneath the waters of the sea began, the region had been worn down to a comparatively smooth surface by long-continued erosion, and seems to have had a low, domelike summit in the present southwestern part of the region, whence it sloped gently away on all sides. The encroachment of the sea was not steady but in oscillatory fashion, but was in general progressive; in other words the waters of the successive seas usually covered a larger part of the dome than their predecessors had done. This was especially true in the northeastern part of the district. Where we today find the Paleozoic rocks we can be sure that the sea was present, but since

they have been worn away from most of the region, the extent of the various seas is highly conjectural. It is quite unlikely that deposits of Potsdam age were ever laid down within the area of the Long Lake quadrangle. But the Beekmantown waters may have reached the district, it is quite likely that the Chazy waters did, and that deposits of Trenton and Utica age were laid down here is highly probable. The thickness which such deposits may have attained here can only be guessed at, but may well have amounted to several hundred feet.

Subsequent history. At the close of the Lower Siluric the sea disappeared from the region and there is no evidence that it has since been submerged. It has instead been a land area, its surface undergoing wear. The altitude above the sea has however been changed from time to time, and whenever it has been increased, greater capacity has been given to the eroding agents. Many millions of years have passed since the close of Lower Siluric time, no one can say just how many, and in that time every vestige of the deposits of that age has disappeared from the surface of the quadrangle, and the Precambric rocks beneath have also been eroded somewhat. What thickness of these rocks has thus been worn away can not be told, but many hundreds of feet seem to have thus disappeared from the hilltops, and from 1000 to 2000 feet more from the valleys. This is a considerable erosion, but apparently of much less magnitude than the great Precambric erosion.

At the close of the Paleozoic occurred the greatest of the Postcambric disturbances of the region. Great lines of fracture were formed, along which slipping, or faulting, of the rocks took place, along with much minor cross faulting. The great faults have a north to northeast course across the district, dividing it into a great series of slices. The cross faults more or less break these up into blocks of varying size, and at various levels. Some slight folding of the rocks also took place, but of very minor amount in comparison with the sharp folding in the New England area to the eastward, and the main displacement of the district was by faulting. Nearly all of the great faults downthrow to the east, producing a rude, steplike drop from the central area down to the Champlain valley. To the eastward, in New England, folds, and large faults which downthrow to the west, occur, resulting in the great down-faulted trough of the valley. In the Long lake area and thence

westward, faults are not so prominent as to the east, and the general altitude diminishes in that direction.

There was a minor period of igneous activity, in all probability of this date, which affected the country east and north from the Champlain valley, but not greatly to the west, and no rocks of this date are known in the area of the quadrangle. The general result of this period of disturbance was to considerably increase the altitude of the interior region.

A long period of comparative stability of level seems to have followed, sufficiently long to have permitted of the wearing down of the whole region to a rather uniform, low altitude, broad valleys with rather low, insignificant divides constituting most of the surface. Numerous hills were however left, with altitudes often several hundred feet above the general level. Following this a general increase in altitude occurred, greatest along the present main axis of elevation, and with likely renewed slipping along the faults on the Champlain side of the axis. The uplift renewed the cutting power of the streams and they excavated the present valleys of the region, the hills representing remaining portions of the previous surface. No doubt many minor changes occurred during this long period, but as mere episodes in comparison with the two greater movements.

Then followed the recent period of cold, and of ice advance over the region. How many advances and retreats of the ice sheet occurred across the Adirondacks can not be told, since the last advance obliterated all traces of its predecessors, at least no traces of them have yet been discerned. The ice plainly covered the region to a depth sufficient to submerge even the highest hill tops, and persisted for a considerable time. It did a respectable amount of erosion, and, when retreating, covered the country unevenly with glacial deposits. On its final disappearance it left the topography modified somewhat, owing both to wear and to deposit, but with its larger topographic features little changed. Ridge slopes were smoothed, summits rounded, valleys clogged with deposit, lakes produced either by inequality of deposit or by local excessive downward erosion, stream courses more or less modified, a host of minor changes in detail, much altering the general appearance of the region.

At the time of final disappearance of the ice the region had an altitude somewhat lower than at present, the amount in the quad-

rangle being some 400 feet in all probability. The altitude has since slowly increased to its present amount, and the upward movement may yet be in progress.[1]

ROCKS

With the exception of the glacial deposits and boulders, and later stream and lake accumulations, all the surface exposures occurring in the quadrangle exhibit crystalline rocks of Precambric age. These comprise not only considerable belts of the sedimentary Grenville rocks, and great batholitic masses of anorthosites, syenites, granites and gabbros, considerably younger than and intrusive into the Grenville rocks, but also large areas of gneisses, which seem for the most part igneous, which can not yet be classified, but which are, at least in part, older than the great intrusions.

Grenville rocks. The most extensive belt of Grenville rocks occurring within the quadrangle's area has its broad northern end penetrated by the upper part of Follensby pond, down whose shores it runs for $\frac{3}{4}$ mile, with greatest breadth on the west side. It extends southward from Follensby to the Moose creek valley, curving toward the southwest as it approaches it, and extends up this valley and its continuation, the Bog stream valley, to the west edge of the quadrangle.[2] As it runs west it narrows to a breadth of less than a mile, which is less than half the average breadth south from Follensby. This will hereafter be referred to as the Moose creek belt.

Another considerable belt of Grenville rocks runs west and northwest from Round island, in Long lake, past Rock pond and Grampus lake to the quadrangle edge, with an outlying small area to the south running west from Grampus lake. No trace of undoubted Grenville rocks could be discovered on the east shore of Long lake, opposite Round island, doubtful gneisses constituting that district. This will be called the Rock pond belt.

A third belt is crossed by the Raquette river just below Long lake, and extends up Cold river some $2\frac{1}{2}$ miles. This very likely extends down the Raquette to a connection with the Moose creek belt, but lack of outcrops in the interval save for a few meager exposures of doubtful igneous gneisses, renders the matter uncertain. This is the Cold river belt.

There is a considerable area of Grenville rocks about the lower

---

1 For a fuller account of the geologic history of the region see N. Y. State Mus. Bul. 95. p. 272–94.

2 See accompanying map.

end of Lake Catlin in the extreme southeast part of the quadrangle. This is likely a northward spur of the great Grenville belt which Kemp has mapped as running east for miles along the Long Lake-Newcomb road, in the Newcomb quadrangle which corners the Long Lake quadrangle on the southeast. At the time Kemp's map was made only the actual limestones and closely associated schists were being included in the Grenville, whereas these rocks are quartz gneisses.[1]

On the Tupper Lake quadrangle, next west of the Long Lake, there is again at least one great belt of Grenville rocks, as yet unmapped, for numerous exposures of these rocks appear for several miles along that part of the Long Lake-Long Lake West road which lies between Little Tupper lake and the railroad.

In addition to these belts there are several patches of varying extent of Grenville rocks occurring within the quadrangle limits, and such as have been recognized are indicated upon the accompanying map.

As usual, most of the Grenville country is valley country, owing to the weakness of these rocks as compared with the other crystallines. In general the outcrops are infrequent, scattered and poorly exposed, so that little or nothing can be done toward deciphering the stratigraphy, or the structure. It is certain that the rocks are considerably folded, and also that the folds pitch, causing frequent changes in the direction of strike. The quartz gneisses form an exception to the general rule. Where present in considerable thickness, as they are about the lower end of Lake Catlin, they constitute respectable hills, several hundred feet in hight, on the sides of which exposures abound.

These quartz gneisses, or schists, constitute a prominent feature in the Grenville series of the quadrangle. They are metamorphosed sandstones of varying degrees of purity, and occur in part in beds of large thickness and fairly uniform character, and in part in comparatively thin beds, alternating with beds of mica gneiss and of impure limestone. These latter quartz schists are much more variable in character than are the thick ones. In general the rock is rather evenly granular, though there are all gradations between a sugary, granuiar, weak rock, and hard, solid, glassy quartzites. In many instances thin layers of coarse, solid quartz alternate with the granular layers, and may comprise upward of half the

1 N. Y. State Geol. 17th An. Rep't. Map opposite p. 550.

whole mass. They are however a much more prominent feature of the thinner, variable beds, than of the large masses.

All these rocks are very quartzose, but all contain feldspars in respectable amount. There are two main types of the rock mineralogically. In one a light-colored pyroxene (a white or light green diopside) is a prominent constituent, while mica (usually phlogopite) if present is subordinate; in the other the pyroxene is subordinate or fails, and mica assumes much greater prominence. The pyroxene rocks are much more apt to be granular and weakly resistant to wear, while the mica rocks are comparable to many of the igneous gneisses in resisting power, hence their tendency to form hills. Much of the rock strongly resembles quite pure quartzite, but careful inspection always shows a considerable feldspar or pyroxene content.

The larger number of the Grenville exposures in the district show a quite varying set of rocks in comparatively thin layers. The quartz pyroxene gneisses described above constitute an important feature. There are frequent, thin, micaceous bands in which, in addition to the mica, there is increased pyroxene and feldspar, and much diminished quartz, and which would seem to represent thin shale bands. Equally frequent are basic bands of hornblende mica gneiss, with black pyroxene and soda-lime feldspars for the other constituents, which have thus the mineralogy of gabbros, but are distinctly interbanded with the sediments. Rather thin bands of limestone occur frequently, generally quite impure, showing more or less pyroxene, titanite and graphite, grading often into border rocks of black, heavy character and composed chiefly of pyroxene. These limestones are interbanded with, and grade into the quartz pyroxene gneisses, producing all sorts of intermediate rocks, so that the series as a whole seems made up of alternate limestones and sandstone bands, with an occasional thin layer of shale. Exposures do not suffice to determine whether thick limestone masses are, or are not present. Ophicalcite was found in one single locality in the Moose creek belt. This general group of rocks is the one represented at the majority of the Grenville exposures of the quadrangle. Next to it in importance is the heavy quartzite group. No sillimanite gneiss was encountered, which is surprising, but not infrequently considerable masses of gneiss, both acid and basic, all cut up by quartz veins, and with frequent bands of solid quartz are met, which look sedimentary but are somewhat doubtful

since in composition they are close to some igneous rocks. But their banded character, and the occasional appearance of thin bands which are quite certainly sedimentary, strongly suggest a sedimentary character for the whole. Such gneisses occur in force in the Moose creek belt, along Bog river. The garnetiferous gneisses, both acid and basic, which usually play such a large rôle in the Grenville make little show in the district, though occurring in small amount here and there.

The Grenville rocks are all cut up by other rocks which seem igneous. Some of these are plainly to be classified with the later great intrusions; but others are quite unlike these. Of these last some resemble phases of the gneisses here classed as doubtful, and shortly to be described, while yet others seem to be peculiar to the Grenville association and not to be found elsewhere. Yet their discrimination is a matter of great difficulty, there are so many phases of the other rocks to be borne in mind. Further their supposed diagnostic characters are much easier to recognize than to describe. Some rocks which seem quite certainly igneous are often apparently interbanded with the sediments, and may represent heavily metamorphosed contemporaneous sheets, or flows, or even beds of volcanic ash. Other rocks which are unquestionably igneous, cut the sediments, and yet have not so far been certainly recognized away from the Grenville association. While indisputably later than the rocks which they cut, they are thought to be not greatly younger, and to be much older than the big intrusions. Yet the whole question is an exceedingly difficult one, and the poor and sparse rock exposures of the Grenville throw little light upon it. Some of these rocks have the composition, or at least the mineralogy, of granites, some of syenites, and some of gabbros. The latter are perhaps more apt to be distinctly interbedded with the sediments than are the others, though all seem to have that occurrence at times.

There seems considerable uniformity of structure in the different Grenville belts. The general strike varies from west to northwest, and the usual dips are to the south and frequently high. In the Rock pond belt the strike varies between n. 30° w. and n. 60° w. in the Grampus lake vicinity, and from n. 60° w. to west nearer Long lake, hence has general parallelism with the trend of the belt. In the Moose creek belt the exposures are very poor and the dips are flat, so that it is difficult to get observations of any pretense to accuracy upon

the strike. South from Follensby pond the rocks are much folded and with a general northwest strike, and south dip, but with much variation in both. This is in sharp contrast with the prevailing and usually high south dips in the Rock pond belt. The high dips occasionally run up to verticality and become steep north, suggesting the truncated tops of closed folds, but the north dip never persists very far. The Follensby Grenville is plainly cut out along the strike by the syenites which lie to the west, as would be expected from their proved intrusive character and later date.

Along Cold river the strike varies from n. 25° w. to n. 50° w. in the few exposures, with a general dip of 45° s., though with much variation and plainly much folding. This strike is very suggestive of the extension of this belt to the northwest to a connection with the Moose creek belt, the proof of which can not be furnished owing to lack of exposures.

About Lake Catlin the strike varies from n. 80° w. to n. 60° w. and the dip is again to the south, and usually under 25°. West of the lake the sediments are much involved with gneisses apparently igneous, which soon cut them out entirely. On the hill in the extreme southeast corner of the quadrangle there is a thickness of close to 500 feet of the quartz gneiss exposed.

No order of rock succession involving the different members of the Grenville could be made out anywhere, and but the vaguest ideas concerning the thickness could be obtained. In addition to the quartz gneiss thickness just quoted, a thickness of at least 200 feet of quartz pyroxene gneiss and impure limestone is shown on the low hill just south of Rock pond. But these are mere local details of what is certainly a great and thick rock series.

Doubtful gneisses. These rocks divide themselves into two main groups: in the one we find comparatively uniform igneous gneisses without sedimentary admixture; in the other frequent bands or patches of Grenville rocks, and also frequent rocks of doubtful nature but with a Grenville look, appear associated with the igneous gneisses. The first group will be styled for convenience the "Long lake gneiss" and the second "the Grampus gneiss." The edge of another great mass of these rocks appears in the extreme northwest part of the quadrangle, and extends widely westward. This will be called the "Piercefield gneiss."

Long lake gneiss. This occupies a large area in the southern half of the quadrangle on both sides of Long lake, constituting the

usual rock which borders the Grenville belts. The exposures exhibit a fairly uniform mass of gneiss, uniform in that it has a certain facies which is readily recognizable. It is not uniform in composition, since it varies from a red, granitic gneiss to a black, gabbroic one, both kinds occurring in many exposures. But the bulk of the gneiss consists of these two sharply contrasted rock varieties. Frequent intermediate varieties occur, and the granitic gneiss shows considerable minor variation; but the group as a whole consists of alternating masses of granitic and gabbroic gneiss.

The granitic gneisses show a twofold facies; most commonly they are finely and evenly granular and quite gneissoid; but mingled with these are many masses of quite coarse, granitic make-up, vastly less gneissoid than the other. In a few cases very quartzose granites of the Morris type, shortly to be described, occur, and they distinctly cut the other and are therefore younger. But in the majority of instances no such relationship is observable, and the distinct impression is created that the one rock is merely a phase of the other; or in other words that the coarse material differs from the fine merely in having locally escaped the excessive granulation which that has experienced.

A red to brown feldspar is always much the most prominent constituent of this rock, comprising from 60 per cent to 80 per cent of the whole.[1] Quartz forms on the average from 15 per cent to 20 per cent, but runs both higher and lower. Black mica (biotite) is the next mineral in importance, though usually accompanied and frequently wholly replaced by hornblende. Both the granites and the granitic gneiss have essentially the same composition, though the latter are usually richer in the black, ferro-magnesian minerals.

Black, amphibolitic gneisses constitute from 20 per cent to 30 per cent of the general mass of the Long lake gneiss. Sometimes they occur in bands only a few feet in thickness with red gneisses above and below, and here they usually appear interbanded, or in other words the contacts are parallel with the general foliation of the mass. From these smaller bands there are all gradations up to very thick masses of large areal extent. For the most part these are hornblende feldspar gneisses, or amphibolites, the feldspar being mainly plagioclase, ranging from andesin to basic labra-

[1] The mineralogy of this and the succeeding rocks will be described in detail in a later portion of this report.

dorite. They range from fine grained, heavy, resistant rocks, to coarse, well foliated masses with conspicuous platy hornblende, which are weakly resistant and easily decayed. In the former type there is apt to be considerable pyroxene in addition to the hornblende. In the latter black mica is pretty sure to develop, sometimes in considerable quantity, assisting the platy hornblende in the development of well marked foliation.

In many cases rocks, distinctly intermediate in character between these amphibolites and the granitic gneisses, have been observed. In no case have they been seen to acquire large bulk, and in no case has it been possible to definitely determine their relationships. But since the amphibolites seem at times to shade into the granites through intermediate rocks of the sort, it is quite likely that we are dealing with impregnation of one rock by the other, with the effect disguised and equalized by the subsequent metamorphism.

In all cases where these amphibolites occur in considerable masses, comparatively unmetamorphosed cores are found which show typical gabbro (hyperite) as the original rock. All such found have been mapped as gabbro, both the unchanged core and the surrounding amphibolite being included. In the case of the smaller masses such definite evidence of origin is lacking, and all such have been included in the general mass of the gneiss. Yet they seem quite certainly to represent the same rock, in the one case only partly, in the other wholly converted into amphibolite by metamorphism. A very accessible mass of such amphibolite is that composing the island toward the lower end of Long lake on which the Island House stands. It does not run into gabbro anywhere within the limits of the island, though it may do so under the waters of the lake near by. On all near-by points on the lake shore the granitic gneisses appear.

For the most part then the Long lake gneiss consists of two sharply contrasted varieties of gneiss, both of which are unquestionably of igneous origin. There then arises the question as to their age relations to each other, and to the other igneous rocks of the quadrangle.

It may be stated in the first place that small masses of similar rocks are found involved with the Grenville sediments, and apparently cutting them intrusively. So far as it goes this implies their later age, but in the uncertainty prevailing as to the equiva-

lence of these small masses with the main one it is unsafe to say that the latter is younger than the Grenville, though it is quite likely. On the other hand if there are any rocks in the district older than the Grenville they are here.

The gabbro of the unmetamorphosed cores is exceedingly like the gabbro found elsewhere cutting the anorthosite and syenite, and regarded as the latest member of the general eruptive series. This latter is often somewhat metamorphosed, but its metamorphosed phases show about the same mineralogy as the unaffected rock, though recrystallized into a granular rock, and do not run out into amphibolites, so far as the writer's observation goes. The metamorphism of the one seems less profound and of a different type from that of the other. The writer has never found these amphibolitic gabbros in connection with the great intrusives, never except in association with the granitic gneisses, the Grenville rocks possibly excepted. The difference may perhaps be accounted for on the supposition that the inclosing granitic gneisses were less effective as a protecting buttress against the stresses producing metamorphism, than were the massive and bulky anorthosites and syenites. And while this may be true and the two gabbros, notwithstanding their differences, be of the same age, it seems a much less likely supposition than that the one gabbro is much older than the other and its more profound metamorphism thus to be accounted for.

Within the limits of the quadrangle no satisfactory evidence respecting the relative ages of the two main constituents of the Long lake gneiss, the granite and the gabbro, has been discovered. Elsewhere in the Adirondacks however the writer has found amphibolites, in all respects like those produced from the gabbro by metamorphism, distinctly cut by granites very similar to, if not identical with, these granitic gneisses, indicating that the gabbro is older than the granite. Since there is some question as to the precise identity of each of the rocks concerned, it is not safe to theorize too widely. It does however indicate the presence of a gabbro in the region older than a granite, both of which have suffered intense metamorphism; and hence enforces caution respecting the tendency to class all gabbros together because they are gabbros, and all granites because they are granites. While in doubt regarding these Long lake gabbros the writer is disposed to regard them as older than the anorthosite, hence distinct from the later gabbro.

There is the further question, involved with the last, whether the granitic gneiss is a member of the general eruptive series, or is a considerably older eruptive. In part it is to be classed as a granite rather than a granitic gneiss, and this granitic portion may be younger than the rest or may represent less metamorphosed cores of the gneiss, analogous to the gabbro cores of the amphibolite. There is certainly some younger granite in the mass, but the impression given is that most of it is not separable from the gneiss and is simply a less metamorphosed phase of it.

Ogilvie has recently described from the Paradox Lake quadrangle, a gneiss which has many features in common with this granitic Long lake gneiss, if indeed it be not identical with it, and regards it as a granite belonging to the general intrusive group and younger than the anorthosite and syenite.[1] That there is a considerable body of granite in the region of which this is true, the writer is firmly convinced. But he is equally convinced that there is much granitic gneiss in the region which is much older than the anorthosite, and his present disposition is to refer the Long lake gneiss in the main to that group. It would vastly simplify geologic work in the region if Ogilvie's interpretation of the Paradox granite could be shown to be generally applicable to the granitic gneisses of the district; but there are difficulties in the way. The anorthosites and syenites contain not infrequently gneiss inclusions, sometimes of amphibolite, and sometimes granite. These are unquestionably older than the intrusives. Now there are amphibolites and granites associated with the Grenville rocks and the uncertain matter is whether these inclusions are from such rocks, or not. If not they distinctly point to the presence of older bodies of such rocks other than those associated with the Grenville; or else to large bodies of such rocks of which minor offshoots cut the Grenville rocks. The writer has not yet obtained any evidence in the region which satisfactorily clears up these points. So the mapping of these rocks as gneiss is merely a makeshift, indicative of lack of exact knowledge respecting their age.

Grampus gneiss. In the southwestern part of the quadrangle is a mass of gneiss which differs materially from the Long lake gneiss in the considerable diversity shown. It is in association with the Grampus Grenville and shows frequent patches of Grenville sediments of various kinds, which are too small to map on

1 N. Y. State Mus. Bul. 96, p. 484 et seq.

this scale. There are various other gneisses present which are unlike anything found in the Long lake gneiss, except in the near vicinity of Grenville belts, most of which seem igneous, though some are of doubtful origin. Some of these gneisses are easily recognizable, others are discriminated from the Long lake gneiss only with difficulty. Along with all these is a general matrix of Long lake gneiss.

There is, for example, much of a black and white gneiss, which consists of hornblende or pyroxene and plagioclase feldspar, either andesin or labradorite, with accessory apatite, magnetite, titanite and zircon. In most of the occurrences the feldspar predominates, and the rock is spotted in appearance and fine grained. With increasing hornblende the grain becomes coarser and the rock is striped instead of spotted. Often one variety is interbanded with the other. A similarly appearing rock in the field shows pyroxene instead of hornblende, with much titanite and a more acid feldspar (oligoclase). These rocks have the mineralogy of gabbros and diorites, but the field appearance is often suggestive of a sedimentary origin. There is often a strong resemblance to the rock of the "Whiteface" region which Kemp has described as the "Whiteface type" of anorthosite.[1] That rock behaves at times like an intrusive, at others strongly suggests a sediment, and its true nature and relations have not been clearly made out. If an igneous rock, its customary Grenville association has not been explained, and a close association in age is indicated; an age older than that of the ordinary anorthosite.

Another gneiss in this group is a red, usually acid, rock composed of quartz and alkali feldspar, with a considerable content of green pyroxene and a deep colored titanite. This rock is also quite variable and is a frequent rock in the Adirondack region, often associated with magnetite deposits, as at Lyon Mountain. Its true nature, association and age are yet to be discovered.

There is also found much of a peculiar granitic rock, differing in appearance from the ordinary Long lake granitic gneiss, the difference being difficult to describe, though easy to recognize. It is a rock of medium grain, not extra gneissoid, much lighter red than the Long lake gneiss, and contains from 10 per cent to 20 per cent of hornblende, magnetite and biotite. It occurs in a great number of Grenville sections, lying in among the sediments, or cutting them

1 N. Y. State Geol. 15th An. Rep't. 1895. p. 587.

out, both above and below. It also occurs away from them in the general body of the gneiss. It may be a phase of the Long lake gneiss modified in appearance by the incorporation of Grenville material, but this seems unlikely, in view of its composition and it is tentatively regarded as a Grenville igneous rock, one whose injection took place during, or only shortly after, the deposition of that series. It is also thought that there are gabbros of similar age in the region, though no such have been identified within the quadrangle limits.

There are various other varieties of gneiss found in the Grampus vicinity, though of very minor importance compared to those already enumerated. The whole mass is well banded, with frequent variations in composition and gives the impression of a Grenville area so intruded with igneous rocks of all kinds and ages that the Grenville has well nigh disappeared, the whole subsequently excessively metamorphosed. In consideration of its complicated nature, and the trifling amount of certain sediments included, it is thought wiser to give it a noncommittal mapping than to map it separately from the Long lake gneiss.

Piercefield gneiss. In the extreme northwest corner of the quadrangle there appears the eastern apex of a great mass of gneiss which lies mostly beyond the quadrangle limits, and which affords a somewhat different rock admixture from either of the foregoing. The rocks are excellently exposed about Piercefield, and in the railway cuts between Piercefield and Tupper Lake. These latter are on the edge of the main syenite mass, and show excellently two of the varieties of gneiss concerned, and their relations. These are a green, syenite gneiss and a red, granitic gneiss. The former is exceedingly like some of the very gneissoid phases of the syenite, near at hand. In one cut the red gneiss plainly shows an intrusive contact against the green; in another a pegmatite is at the contact, which repeatedly injects the green gneiss along the foliation planes. The pegmatite is a granite pegmatite, and seems to be a phase of the red gneiss. In both cases the green gneiss, which is quite hornblendic everywhere, becomes excessively hornblendic near the contact, and this is regarded as a contact phase of the green gneiss, though it is an unusual contact rock. Here is a syenite cut by a later granite, and a large mass of syenite near at hand. It would seem most probable that the two belong together, but they do not look alike, there are some differences in their mineralogy, and some

slight differences in their chemical composition also. Much of the red gneiss is of the type which contains green pyroxene and deep colored titanite, like that described from the Grampus lake area, and some of the green gneiss has the same minerals in abundance. There are also other gneisses present in minor quantity. It is quite likely that the green gneiss actually belongs with the main syenite mass, its differences being due to the granite intrusion. If so then in all probability most of the Long lake and Grampus gneiss should be classed with this granite as a great bulk of granite intrusive, later than the syenite, as Ogilvie has argued for the Paradox lake area. Owing however to the differences between the two rocks the writer hesitates to adopt this view without more decisive evidence, and has again taken refuge in noncommittal mapping.

Great intrusions

Anorthosite. A great mass of this rock lies in the northeast portion of the quadrangle and comprises about one fourth of its area. It is but a small segment of a great batholite of the rock which has a wide extent in Essex and Franklin counties, and forms the larger part of the surface of the three quadrangles, Santanoni, Saranac and St Regis, which bound the Long Lake quadrangle on the north and east. It represents the earliest of the great intrusive masses which invaded the region in Postgrenville times. It is one of the most easily recognizable rocks of the Adirondacks, and its area is accurately mapped, so far as surface exposures will permit.

This great mass of molten rock ascended to its present position and solidified, not at the surface but underneath a great thickness of overlying rock. This cover, and the upper part of the anorthosite itself, have since been removed by slow surface erosion. The present surface extent of the rock is simply the area of the original mass at the horizon where the present erosion surface cuts it. We can only conjecture as to its extension downward, though it no doubt runs deep and broadens downward. The amount worn away from the surface is less conjectural. Sections of the rock of above 3000 feet in thickness are exhibited in some of the mountains which it composes, suggesting the removal of at least that amount from the neighboring valleys, with an additional unknown amount from the summits. This however necessitates the assumption that the original upper surface of the mass

Anorthosite ledges by Indian carry, near Rustic lodge

was comparatively even, which is far from likely. Near the present borders of the mass inclusions of the older rocks are found, suggesting that here we are near the actual upper limit. Since the rock was formed the mass has been much dislocated by faulting, shifting the relative levels of the old surface in the various fault blocks. This also urges caution in assuming that 3000 feet or more have been generally worn away from the valley regions, and also renders it certain that quite different amounts have disappeared from the surfaces of the various fault blocks. If however the present surface were not far beneath the original surface it would seem that inclusions of older rocks should be more common than they are in most of the anorthosite district, and that we should also find downfaulted blocks of other rocks within it. So far as the writer is aware, such phenomena are mainly confined to the borders, and thus a quite respectable amount of wear from the upper surface is argued.

The rock solidified as an exceedingly coarse porphyry, large crystals of labradorite feldspar, often several inches in length, abounding, surrounded by smaller crystals of the same material, for as a whole the rock is made up of this mineral, other constituents being present only in very minor degree. The large crystals are of deep, blue-black color, often iridescent, and show bright, glistening cleavage faces, on which twinning striations are usually plainly observable. Originally the remainder of the rock was of the same color and in the least metamorphosed portions, when unweathered, it is today.

Changes of composition are observable, both locally within the mass, and quite uniformly as its border is neared. These consist in increase in amount of the other rock constituents, with corresponding diminution of the feldspar. This may continue until they equal the feldspar in amount, and in exceptional cases exceed it, but these are extreme phases and one rock slowly grades into the other. These other minerals are augite and titaniferous magnetite, which are present everywhere in the rock in small quantity, and hornblende, hypersthene and garnet, which are not everywhere present, but are universal in the less feldspathic portions. Chalcopyrite is a widespread constituent, though in small quantity. The garnet commonly forms zonally around the magnetite, separating it from the feldspar, and the black center with the red zone of garnet surrounding it is a very common

feature of the rock containing these constituents. Most of the anorthosite of the quadrangle contains garnet and the black minerals in noticeable quantity, owing to its comparative nearness to the border.

Like the other Precambric rocks the anorthosite has been much metamorphosed, being crushed or granulated and somewhat recrystallized. But owing to its original very coarse texture, and to the fact that granulation mostly commences at the edges of crystals and slowly works its way inward, the rock does not appear so thoroughly metamorphosed as do the other rocks, none of which approached it in original coarseness of grain. The crushing which would have completely granulated a more finely crystalline rock would only partially destroy the large labradorite crystals, and uncrushed cores of large or medium size would remain, even in the most excessively metamorphosed portions of the rock. With increase in the amount of dark minerals present the original grain of the rock seems to have been progressively less coarse and such rock is generally more completely granulated, with the uncrushed feldspar cores fewer in number and of smaller dimensions. This is a more common rock within the quadrangle than the coarser and purer variety.

In some portions of the rock the feldspar crystals are more numerous, are smaller and are all arranged with their long axes parallel. This is a "flow structure" due to movement in the mass during solidification, which has strung out the already formed crystals into parallel arrangement.

The granulated portion of the rock varies in appearance according to the fineness of the crushing. In the majority of instances where not too finely granular, it has a grayish green to grayish blue tinge weathering to brownish. In more severely mashed portions the grain is very fine, gray to white is the color, the rock is very dense and hard, and uncrushed crystals much less frequent and of smaller size. Sometimes locally, either near bodies of later intrusives, or else in badly sheared portions of the rock, the feldspar has been largely altered to a dull, white or greenish white material known as saussurite. This is quite different material from the soft products of surface decay of the same mineral. Rock of this sort makes up the rock point on the east bank of the Raquette river ½ mile below the Raquette Falls landing. Similar material occurs at various places in the woods.

Gabbro border of the anorthosite. The gradual change in composition outlined above continues until, as an extreme product, a rock is obtained in which the heavy, dark colored minerals equal or exceed the feldspar in amount. A steady diminution in coarseness of texture accompanies this change, the uncrushed feldspar cores become continually smaller and less numerous till they finally disappear, and foliation becomes more and more prominent, so that the final product of the change is a heavy, dark colored gneiss which bears no resemblance whatever to the normal anorthosite, and would not be recognized as a variant of that rock by an observer who met it for the first time, coming upon it from without the anorthosite area. If approached from the other side however the steady change from one rock into the other is plainly manifest. This final rock is not anorthosite but gabbro, and the rock intermediate between the two may be called anorthosite gabbro. It is perfectly evident from the field relations that this border phase of the anorthosite was produced by some process of differentiation in the general mass of igneous material after it had reached its present resting place, prior to or during solidification.

For the larger part of its extent across the quadrangle the syenite, to be next described, adjoins the anorthosite, and a moment's inspection of the geologic map makes it evident that it has encroached upon, and cut out the anorthosite border to some extent. Between Follensby pond and the Raquette is a considerable mass of syenite which cuts out nearly the whole of the gabbroic border locally, and holds great inclusions of it likewise. In the Tupper Lake vicinity also the anorthosite has been badly cut out by syenite, and here again much of the gabbro border has disappeared. Outside the limits of the quadrangle there are localities where the gabbro border is lacking where its nonappearance is clearly owing to faulting. It is quite likely that originally the entire anorthosite area was characterized by such a differentiation border.

In addition to this border differentiation to gabbro, a similar change has also taken place here and there within the general anorthosite mass. A prominent area of the sort occurs near Panther pond, within a mile of Upper Saranac lake, which has been mapped as gabbro. As it is approached the anorthosite becomes rapidly more gabbroic, but at the same time dikes of gabbro appear, cutting the anorthosite and in regard to the gabbro center it is not certain

whether it should be classed with the anorthosite or with the gabbro dikes. But these latter do not seem to be greatly younger than the general mass, and quite likely represent the injection of a portion of the mass which had already solidified by material from a yet liquid portion.

Within the Santanoni quadrangle, next east, local differentiation has produced the masses of titaniferous iron ore of the Lake Sanford and Lake Henderson region.[1] These are well within the anorthosite mass with quite pure anorthosite for the general wall rock, and are remarkable for the narrowness of the gradation zone. No such masses, large or small, have been noted within the Long Lake quadrangle.

This border gabbro is a rather uniform grained rock, of sufficient coarseness so that the white of the feldspar, the red of the garnet, and the black of the pyroxene, hornblende and magnetite are all prominent. In the less extreme phases of the rock, occasional small uncrushed feldspar cores remain. But the small, glittering, lath-shaped feldspars which are prominent in the less metamorphosed portions of the gabbros associated with the Long lake gneiss have not been noted in this border rock, and the distinction is believed to be characteristic of the two rocks.

Anorthosite outliers. Three small outlying masses of anorthosite have been noted within the limits of the quadrangle, and doubtless there are others which have been missed, or which are covered by glacial deposits. Only masses rather remote from the main body are here under consideration. Curiously all three are in Litchfield park. They are from 4 to 7 miles distant from the main mass, with an intervening broad belt of Grenville rocks. To account for their presence here, and their nonappearance elsewhere is a difficult problem. In but one case do the exposures suffice to give any clue to their relationships to the surrounding rocks.

The more northerly of the three outliers forms the summit of a small hill which lies between Jenkins and Long ponds. The hill breaks down quite steeply on the north and west in bare rock cliffs, was burned over some years ago, and second growth has not yet gained a foothold on the bare rock, so that exposures are excellent. The hill also forms an easily accessible and excellent viewpoint in all directions but eastward.

In going north to the hill from the road between Jenkins and

1 Kemp, J. F U. S. Geol. Sur. 19th An. Rep't, pt 3, p. 409–17.

Long ponds, the rock at first is the granitic phase of the syenite, cut by dikes of fine grained red granite. This is shortly replaced by a variable rock which seems clearly a basic phase of the ordinary syenite, also cut by the red granite. At the extreme top is the anorthosite, extending about 300 yards in a northeast-southwest direction. The rock is quite typical, is medium grained, and labradorite feldspar constitutes 95% of it, magnetite, augite, chalcopyrite and apatite being the other minerals. Not only is the passage from the syenite to the anorthosite abrupt, but in addition the latter is all cut up by dikes of the former, both large and small. It is also cut by dikes of the same red granite as that found cutting the previous rocks.

On its northwest side the anorthosite is cut out by a reddish syenite whose relations to the main syenite are not absolutely certain, though if it be not identical it is a closely related rock. Red granite again occurs cutting both the other rocks. The anorthosite is badly cut up by them and has been much altered in appearance, likely by the heat and gases given off by the invading molten rock. The feldspar has been mostly converted to saussurite, producing a dull, white rock.

This exposure, though small, is of much interest in that it clearly shows anorthosite cut by syenite, which is therefore younger, and granite cutting both the others and therefore youngest of all, the anorthosite being entirely surrounded by the other rocks, and therefore an inclosure in them. A plausible explanation of its position, so remote from the main mass, and its inclosed situation in the later eruptives may be made by the following assumptions: that the anorthosite batholite originally extended to the locality, or else sent a large offshoot to it; that the later syenite invaded it and cut it out from beneath, sending out at the same time the big tongue of syenite which cuts out the anorthosite clear to the Raquette river; that the anorthosite inclusions indicate that the present surface is not far beneath the original upper surface of the syenite; that Grenville rocks originally overlay the whole, and have since been removed by erosion; and that later trough faulting dropped the block of Grenville that lies between, so that it has been less worn away, the syenite and anorthosite beneath still retaining a Grenville cover. though it has disappeared elsewhere.

The second anorthosite outlier is near the county line (Franklin-Hamilton) 1½ miles from the west edge of the quadrangle. On the

south syenite gneiss adjoins it, and on the north granitic gneiss and amphibolite, similar to the Long lake gneiss. Unfortunately no contacts are exposed so that the interrelationships of the rocks are most uncertain. Since the previous outlier proved to be an inclosure in later rocks it would be natural to regard this as probably a similar occurrence. The rock however differs from the last, is much mashed, the feldspar shows wide variation in composition, especially considering the small size of the mass, and much scapolite has developed. It is not impossible that it may be a small outlying intrusion, connecting beneath with the main mass, and with the syenite cutting it out on the south. The rapid changes in character from place to place which it shows are more readily explicable on that supposition than if it is regarded as a small fragment detached from the main mass. But the whole question hangs upon the age of the granitic gneiss, and it is therefore doubly unfortunate that no contact appears. If the gneiss is older, this is a small separate intrusion, or branch from the main intrusion; if the gneiss is younger it is certainly an inclosure.

The third outlier is upon the county line, 2 miles east of the second. It is completely surrounded by gneisses of uncertain nature and age, and no contacts are exposed. The rock is very gneissoid, no feldspar cores whatever remaining in much of it. It also holds from 10 per cent to 20 per cent of minerals other than feldspar. The feldspar is an acid andesin instead of labradorite, being in this respect like some of the feldspar of the previous outlier. Both rocks are quite different from the ordinary anorthosite, while the rock from the first outlier is quite normal. This is but natural if the two latter represent small intrusions into earlier rocks.

Syenite. The general syenite of the Adirondacks has a much more irregular and patchy distribution than has the anorthosite, and the present day surface exposures belong to a series of separate masses both large and small. One of the greater of these masses, the Tupper syenite, has the larger part of its present surface within the quadrangle limits and, with the exception of a few outlying intrusions which are likely offshoots from it, is the only syenite mass within the quadrangle. It is separated into a smaller eastern, and a larger western portion by the Follensby Grenville. But if that lies in a downfaulted trough, as seems highly probable, the syenite may be legitimately regarded as continuous underneath, so that the separation into two masses is only apparent, and due to faulting.

Plate 2

Glaciated ledges of augite syenite forming a small rock island in Tupper lake, and similar knobs on the shore

The rock is exceedingly variable, much more so than is the anorthosite. All the varieties grade into one another, so that any separation in mapping is an arbitrary matter, necessitating the drawing of boundary lines where none exist. Yet the extreme variations are so unlike the normal rock as to require separate rock names, and must be given a place upon the map, even at the cost of arbitrary boundaries.

Normal syenite. This is a green to grayish green rock when fresh, with a rapid color change on exposure to the weather, assuming a yellow-brown tinge and then becoming a rusty brown, the normal color on exposed surfaces. Over most of the district the weathered crust is not thick, and in any opening in the rock the normal green is quickly reached. It is a highly feldspathic rock, only second to the anorthosite in this respect, but carries from 10 per cent to 20 per cent of other minerals, quartz, pyroxenes, hornblende and magnetite. Quartz never wholly fails, though not rising to large proportions in the normal rock. The pyroxenes are peculiar, and characteristic. The feldspar (microperthite) is of an entirely different nature from that of the anorthosite, is never iridescent, and does not show twinning striations on cleavage faces.

The original rock was not so universally porphyritic as was the anorthosite, was seldom coarsely so, and even where coarsest was not comparable to the anorthosite in that respect. Hence, though the two rocks have experienced substantially equivalent metamorphism, the syenite has mostly been mashed by the process, uncrushed feldspar cores being very few and very small in comparison with the anorthosite. They are generally present in the normal rock however. For this reason the syenite has a more gneissoid look, and an appearance of greater metamorphism which is deceptive.

The variations of the rock are in two main directions. In the one case the dark colored minerals increase in quantity at the expense of the feldspar, garnet appears, and quartz diminishes and disappears. The syenite passes into a monzonite and ultimately into a shonkinite. The rock also becomes more even grained and gneissoid, as does the anorthosite in its similar variation. The more basic varieties have the dark minerals equaling or exceeding the feldspar in quantity and so strongly imitate the gabbro gneisses of the anorthosite border that they are exceedingly difficult to distinguish. In fact distinctly intermediate

varieties appear, strongly suggesting that one rock has been modified by incorporating material from the other.

In the other direction the rock changes by increasing quartz. The quartz also tends to appear in coarse leaves, or spindles, which are very prominent on the weathered surface or in the hand specimen. The feldspar also changes slightly and tends to become red instead of green producing green and red mottled rocks. Finally the red predominates and the rock becomes a distinct granite.

Basic syenite. This is in general a rather finely granular rock of general black color but sufficiently coarse so that the component minerals plainly show their proper colors to the eye. The feldspar is usually brown, though it is green where fresh material can be obtained. Garnet is in general not so prominent as in the gabbro, and the rock tends to a finer and more even grain, but the differences are slight. In general these basic rocks are confined to the near vicinity of the anorthosite, though in the ordinary syenite there is much variation from place to place in the percentage of dark colored minerals. It will be later shown that, even in thin section, it is very difficult to distinguish these rocks from the gabbros owing to the lack of distinctive features in the feldspars, but that chemically they are easily separable.

Granitic syenite. As mapped this comprises a mass of very variable rock, much cut up by later granite, excellently exposed in Litchfield park and in the two big ridges which run north from it. Admirable exposures, often blasted, are found along the park roadways. Much of the rock is alternately green and red, quite quartzose, and a rock distinctly intermediate between syenite and granite, often passing into granite. Much of it is uniformly red, and the red rocks range from syenite to granite in composition. It is not certain that all these latter rocks are of the same age, and differentiate in place of the main mass, and this is especially true of the red syenite. But it is certain that much of the rock has this character, and the whole is manifestly bound together as a mass of eruptive material arising from a common magma. It is all cut up by dikes and larger masses of a red granite, mostly too small to map separately, a rock to be shortly described as the Morris granite.

Asymmetry of the syenite differentiation. The formation of a gabbro border to the anorthosite by some not well understood process of differentiation, has been seen to be a rather uniform

Plate 3

Ledges of red quartz-syenite, strewn with glacial boulders; north shore of Jenkins pond, Litchfield park

feature of that rock. The syenite presents a sharp contrast in this respect, in that its differentiation is prominently asymmetric, and that, in the case of the Tupper syenite at least, this seems conditioned on the nature of the bordering rock. The most of the basic syenite, and all of the more gabbroic of it is in close association with the anorthosite gabbro border; and the same feature is noted around the large anorthosite inclosures in the syenite. It is also true of the syenite bordering the anorthosite outlier in Litchfield park, this being the only basic syenite which occurs anywhere in the vicinity, so that its presence is especially significant. The differentiation into granite takes place on the south side of the mass, the bordering rock on the south being granitic Long lake gneiss. In each case the syenite grades into a rock approaching in character the adjacent rock. Now the syenite is unquestionably younger than the anorthosite, as will be immediately shown, and the observed relations seem to point to the conclusion that the change is due to the actual digestion, by the molten syenite, of material from the adjacent gabbro. The relations on the other side are not so clear, since the age of the bordering granitic gneiss there is unknown. If it be an older rock, as it is tentatively held to be, then the asymmetry of the syenite is certain. But if it should prove to be a younger granite then the view may be legitimately held that this granite has cut away a large part of the original syenite mass, thus accounting for its apparent asymmetry. In consideration of the great amount of syenite that must be regarded as having disappeared on this hypothesis, however, it is vastly less probable than the other. In this connection it should be recalled that the Diana syenite, as described by Smyth, shows a quite similar asymmetric differentiation.[1] The character of the differentiation may thus be regarded as reasonably certain. The explanation to account for it, namely the incorporation of material from the adjoining rocks, is much more open to question.

The syenite younger than the anorthosite. Reconnaissance work in this district in previous years had led the writer to believe the syenite to be younger than the anorthosite and the evidence then obtained was set forth.[2] It was not however demonstrative, and as the matter is one of considerable importance in Adirondack Precambric geology, it was hoped that a detailed survey of the

1 N. Y. State Geol. 17th An. Rep't. 1897. p. 471–86.
2 N. Y. State Geol. 20th An. Rep't. 1900. p. r41–52.

boundary between the two rocks might furnish proof of its verity. This was in fact one of the principal reasons for the selection of this quadrangle for detailed study. The hope was fulfilled, the evidence being as decisive as could be desired.

About Raquette falls, on both sides of the river, anorthosite and syenite are found in mixed distribution. All exposures are in the woods, in no case was any contact observed, and it is only by the relative abundance and distribution of the two rocks as brought out by the mapping that it is inferred that east of the river the syenite is present as small bosses or large dikes, cutting the anorthosite, while west of it the anorthosite has been largely cut out and mostly occurs as inclosures in the syenite.

The evidence given by the first anorthosite outlier in Litchfield park has been already presented. The anorthosite is definitely cut by syenite which sends dikes into it. The syenite is of the basic variety in part, and in part is reddish syenite; the whole is surrounded by a zone of mixed rocks, granitic syenite and granite which, though believed to be mostly a differentiation phase of the syenite, lies between it and the normal syenite farther north, preventing the definite tracing of one rock into the other.

It is along the northern edge of the quadrangle, where the land has been cruelly lumbered of late years, where the great fire of May 1904 made a clean sweep of what was left, and where much of the land has since been cleared, that the decisive evidence was obtained. Even as far east as Upper Saranac lake occasional dikes are found cutting the anorthosite. These are narrow; the dike rock is fine grained and peculiar and of two main types. One is a hard, ringing, light colored, feldspathic rock, with frequent small garnets, but with other dark minerals present but sparingly. The other is a dark, heavy, gabbroic-looking rock, with abundant garnet. From its appearance in the field it might be either a gabbro or a basic syenite. Now while these rocks suggest syenite in appearance they differ much from the main body of the rock, which shows no similar phases. Yet it is obvious that the physical conditions under which they cooled differ so much from those under which the larger masses solidified, that a considerable difference in appearance and character is normal, rather than abnormal. And the study of thin sections led to the confident belief that they were really dike offshoots from the main mass prior to the discovery of decisive field evidence.

The series of exposures that decisively settle the question occur along the Wawbeek road within the first 4 miles eastward from Tupper Lake. In the neighborhood of the village itself the rock is quite typical augite syenite, though with a tendency to become basic locally, well shown in the road metal quarry near Raquette pond, where the rock is very hornblendic and lacks feldspar augen [pl. 18]. The syenite runs eastward for about a mile, then for an equal distance there are no outcrops, after which they are numerous on both sides of the road, the best and most continuous being south of it, where exposures run with practical continuity for another mile. The rock is chiefly anorthosite, somewhat gabbroic, but by no means the normal border gabbro,

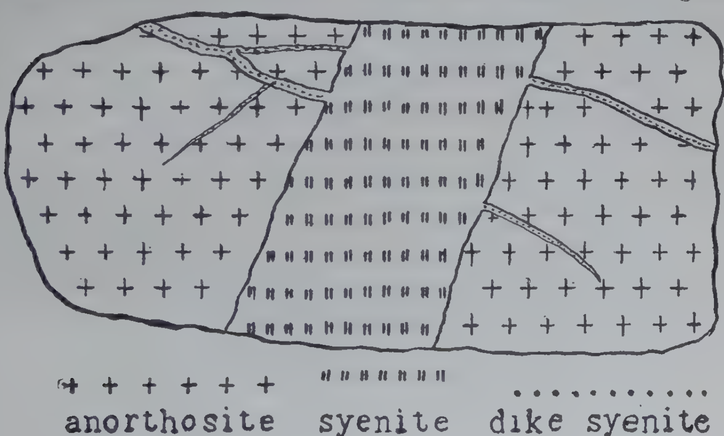


Fig. 1 Relationship of syenite and anorthosite, as shown in an exposure 2 miles northeast of Tupper Lake village, and not far south of the Wawbeek road. Scale 1 inch = 3½ feet

this of itself suggesting that part of the mass has been cut away by the syenite. In addition it is everywhere cut through and through by dikes of the syenite, both large and small, and in increasing number as the main syenite mass is neared. The wider dikes show a rock identical in all respects with the syenite about Tupper Lake, sometimes basic, at others not so, and there can be no question that they represent direct offshoots from the main intrusion, cutting into the anorthosite. From these larger dikes, composed of normal syenite, slender branches may be seen running out into the anorthosite, and in these the rock is at once recognized as identical with that found in the more remote slender dikes, giving a demonstration of their origin, and of the fact that they differ from the ordinary rock because of their slenderness, and hence more rapid cooling. In figure 1 is given a

sketch of a portion of one of these surface exposures, which shows the observed relations clearly. Just adjoining it on the east is an exposure which shows chiefly syenite, but with inclosed blocks of anorthosite. In these exposures neither of the two rocks has the extreme basic character of the usual border phase of each, though the syenite is more basic than the normal rock.

Granite. Both the anorthosite and the syenite, especially the latter, are found cut by dikes and larger masses of granite. So far as the writer's experience goes this granite is always of a single, easily recognized type which he has called the "Morris granite," from its frequent occurrence on Mount Morris, south of Tupper lake. This is a quite uniform, red, very acid granite, constituted almost wholly of red feldspar and quartz, other minerals being usually not visible to the eye. It presents both a fine grained and a coarse phase, the former being more common. The coarse type is especially distinctive because of the segregation of most of the quartz into coarse leaves or spindles, which are very prominent in both the weathered and unweathered rock, and stripe the red feldspar with streaks of dark, glassy quartz. In the other and more common type the quartz shows as small, dark colored, glassy spots in the prevailing red of the yet finer grained feldspar. In some exposures the fine type appears as a border phase of the coarse and the coarse type has not been seen without the presence of the other also. The fine type however frequently occurs without the other being present, the narrower dikes of the rock are always composed of it, and some of the larger ones also. The coarse is not only found grading into the fine, but also appears cut by it.

The granite produced as an extreme phase of the syenite differentiation differs much from the Morris granite in appearance. It is usually coarse grained, though running locally into fine types, is quite hornblendic, and is not especially quartzose. The black blebs and streaks of hornblende distinguish it sharply from the Morris type. In the coarse varieties the quartz tends to assume the leaf form, but the quartz is usually subordinate to the hornblende in prominence. Varieties however do occur which are distinctly intermediate between the normal types.

These two granites belong unmistakably to the general group of the later intrusives. Similar rocks are found here and there within the general body of granitic gneisses of the region. But

their presence does not aid in the general solution of the problem as to the age of the bulk of this gneiss, since if it be older it would be apt to be cut, here and there, by outlying masses of the later eruptives. Such masses are frequently found in it, but in general the evidence does not permit the determination of their character, whether they cut the gneiss or belong with it.

Gabbro. The gabbros are dark colored, basic rocks, usually showing a reddish tinge owing to the presence of garnet. As found within the quadrangle the rock occurs mainly in the dike form, and these dikes have been noted cutting all the other eruptives, with the exception of the granites, leaving the relative ages of the two somewhat in doubt though the granite is thought to be the older. In addition to the dikes is the small boss which cuts the anorthosite south of Panther pond. The rock for the most part is tough and resistant, and generally rather evenly granular. It lacks the gneissoid character of the gabbro border of the anorthosite, and weathers much less readily than that. It has not been noted grading into amphibolite, after the fashion of the gabbro found with the Long lake gneiss. The smaller masses and the dikes of that rock are always found in the amphibolite condition, and this more metamorphosed condition seems to argue a greater age, though it is possible to explain it as due to local causes. The unchanged cores of that gabbro have also a more pronounced ophitic structure than has been noted in this later gabbro, though that also tends toward the same structure in the larger masses. It is only with the greatest difficulty that the rock can be distinguished from that of the dikes of gabbroic syenite. This will be later reverted to.

As a possible exception to the above statement the gabbro knob at the farm in Litchfield park, just west of Jenkins pond, must be instanced. This is thoroughly metamorphosed to a micaceous amphibolite, yet is an unquestioned gabbro; nevertheless it is entirely surrounded by granitic syenites, regarded as belonging to the later eruptives. Unfortunately no contacts show and the relations between the two rocks can not therefore be made out. It would seem to be easiest accounted for on the assumption of a knob of later gabbro cutting the syenite. It is rather large for an inclosure in the syenite, yet the writer's present disposition is to regard it as such, since the Long Lake gneiss is close at hand to the south. If it be not, it of course vitiates the attempt made above to

discriminate between the two gabbros on the basis of difference in character.

Diabase. But two dikes of this rock have been noted within the quadrangle limits. The larger and more accessible of the two is on Round island, in Long lake, showing the usual dense, heavy, black rock with chilled borders and coarser center, and with occasional porphyritic feldspars. On the southeast edge of the island both contacts with Grenville rusty gneisses are exposed, showing the dike to be 30 feet wide and to bear n. 30° e., and that it is not vertical but dips 60° s. No fresh material could be obtained from the dike but it is one of the ordinary olivine diabases of the region.

The other dike was noted on the south slope of an anorthosite hill on the east edge of the quadrangle. Neither contact showed and there was but a single exposure so that its thickness and trend can not be stated. It is an ordinary nonporphyritic diabase. Two other similar dikes are known just west of the quadrangle limits on the Tupper lake sheet, and a few have been located on the comparatively unexplored and rugged Santanoni quadrangle, just east. They are infrequent in the mid-Adirondack region, though abundant farther east.

ROCK STRUCTURES

Foliation.[1] The rocks of the northern half of the quadrangle are chiefly massive eruptive rocks, in which foliation is absent, or at best only rudely developed. This is mainly owing to their highly feldspathic character, and the scarcity of the minerals which are good producers of foliation. The gabbroic anorthosite and the basic syenite have it much better developed, and the tendency of the quartz to assume the leaf type is responsible for a poor foliation in some of the granites. Conspicuous foliation is only found in the Grenville rocks and portions of the Long lake, and Grampus gneisses.

In the Grenville sediments foliation and bedding correspond, in all cases in which it has been possible to determine their relationship. But the Grenville rocks cover such a comparatively small portion of the area, exposures are so infrequent and in general so poor, and the stratigraphy of the series is so little known, that scant idea of the general structure could be obtained from the usual methods.

1 Foliation is a convenient term for that variety of flow cleavage found in wholly crystalline rocks, which have wholly or largely recrystallized under pressure, and which hence possess a parallel arrangement of mineral particles, resulting in a capacity to split more readily in one direction than in any other.

In the Moose creek belt the dips are so flat that they can seldom be made out with certainty. Elsewhere they are higher, and in a few instances distinct folds are shown. These are of the sharply pinched, or closed type, steep south dips becoming vertical and then steep north. But north dips are exceptional. Such folds as show pitch show it to the west or northwest, but it can seldom be made out.

Since no aid could be obtained from the stratigraphy in deciphering the structure of the region, it was hoped that some light would be thrown on it by a careful plotting on the map of all the observations on the foliation dip and strike [*see* map]. In many of the exposures only the strike can be made out, and this is notably the case in the poorly foliated eruptives. Even in the gneisses the foliation is often poor and indistinct, making exact observations difficult, and the whole result is indecisive and disappointing.

Taking the quadrangle as a whole, nearly east and west strikes prevail, and the prevalent dip is southward. This either indicates comparatively little folding, or else isoclinal folding, or else that the foliation does not coincide with the bedding and so does not bring out the folding. It is not possible to demonstrate which of these alternatives is the true one, though the second is very unlikely, and all the direct evidence obtainable is against the third. The south dips vary widely in amount, and there is certainly considerable local folding. In spite of the uncertain nature of the result, certain facts are brought out.

The foliation is more erratic in the eruptives than in the gneisses and Grenville rocks.

In the southeast the prevalence of east and west strikes and south dips is noteworthy. In the southwest the strike has swerved to an average n. 65° w. direction, the dip remaining south. Meridional strikes are exceptional and most frequent in the central portion of the quadrangle. Locally, on the northwest, north dips prevail. There is a local prevalence of northeast strikes about the foot of Long lake. The general nonfoliated character of the anorthosite is brought out by the absence of observations in the territory occupied by that rock.

It is obvious that these observations must be extended over a wider area before their significance can be apprehended.

Joints. The number of readings taken on joints within the quadrangle limits is 647. When tabulated in respect to direction (all odd degree readings being reduced to the nearest 5° direction)

they are found to run in all possible directions [fig. 2]. In individual exposures the majority of the joints are seen to be curving instead of straight. This shows that some latitude in direction must be allowed each joint set, but is not decisive as to the amount of allowance necessary. Few exposures show more than two good sets of parallel joints, though some show three and even four. Certain compass directions are frequent in certain portions of the quadrangle, and utterly fail elsewhere, indicating a shifting of direction, rather than a different joint set, it is thought. From the best exposures it can be learned that in general there are two sets of joint couples, each couple consisting of two sets of parallel joints which

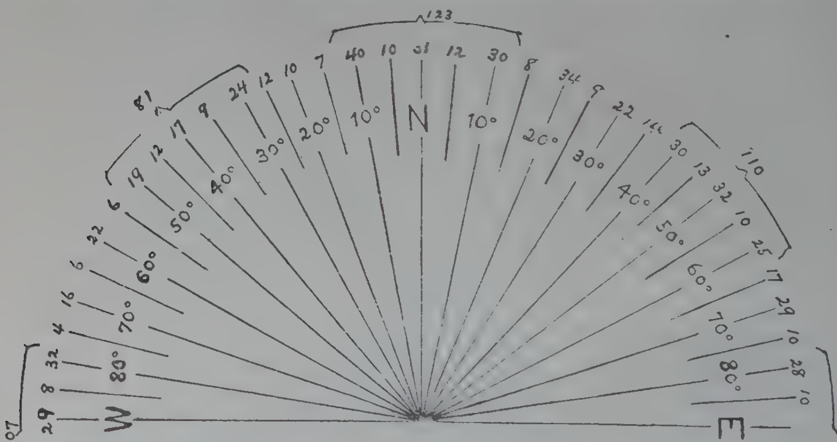


Fig. 2 Diagram of the readings on joints within the Long Lake quadrangle. The inner figures represent the compass degrees east and west of true north; the outer row the number of joint readings observed for each 5° direction. Four numerical groups are also indicated.

approximate a right angle with one another, and that one couple tends to occupy the meridional and equatorial directions, the other running northeast and northwest. An attempt may be made to classify the entire number of readings on this basis, assuming that each set has a variation in direction of 20° owing to swerve. Thus the n. 80° e. to n. 80° w. joints are grouped together, forming a couple with the n. 10° e. to n. 10° w. joints; in like manner the n. 40° e. to n. 60° e. and n. 30° w. to n. 50° w. joints are grouped. The numerical results of this grouping are indicated in the diagram, and a greater number of the readings are included, on this basis of subdivision, than on any other possible basis using the same amplitude of swerve. It is quite certain that some of the joints have a swerve of this amount, but it is not impossible that they may have even more.

Plate 4

Cliff at southwest end of Bluff island, Big Tupper lake, showing joints, the cliff face itself being along a n. 40° w. joint

This grouping still leaves a large number of not included joint readings, especially in the n. 20° e. and n. 70° e. directions. This is either indicative of two additional sets of joint couples, a n. 20° e. to n. 70° w., and a n. 70° e. to n. 20° w. couple, or else shows that the amplitude of swerve in the original couples is considerably more than 20°. If it be as great as 40° the extreme directions of swerve of adjacent pairs would meet, or overlap. But it is very improbable that the amount is as great as this.

If the region consists of faulted blocks, as is quite likely, and if the joints are older than the faults, also highly probable, then a reasonable and probable explanation of the apparent confusion would be furnished. Both hade and throw vary along faults, causing some change in horizontal orientation in the various fault blocks, which may at times become considerable, and produce an equivalent shifting in the directions of preexisting joints. Hence the prevailing joints in adjacent fault blocks might well show a lack of accord in direction, thus accounting for the prevalence of certain joints in certain districts and their absence elsewhere. For example in the southwestern part of the quadrangle the more common joint directions are n. 10° e. and n. 50° e., the latter set more variable in direction than the former. The set at right angles to the first is still more variable, from n. 80° e. to n. 80° w. in direction, while the northwest set is most variable of all, and happens to be the strike joint set. In the southeast the n. 10° w. direction is the most prominent, there are no n. 10° e. joints and but one reading to n. 50° e., the two prominent directions in the southwest. The n. 80° e. to e. and w. direction is next in prominence and is the strike joint set. The northwest set is again very variable in direction.

In the fairly massive eruptives, where there is little or no foliation, the joints are mainly highly inclined to vertical. Hades up to 20° from the vertical are common, especially in the curving joints. But there is often present a set of nearly horizontal joints, also quite irregular.

In the gneisses of the southern half of the quadrangle there is a joint set which is plainly dependent upon the foliation. This varies in general from a n. 80° e. to a n. 50° w. strike, and in many exposures good dip joints are seen whose strike is nearly or absolutely identical with that of the foliation. There are seen also to

be two sets of joints with this strike, a set of dip joints, dipping with the foliation which is to the south in general, and another set at right angles dipping north [*see* pl. 4]. These would seem quite certainly to be compression joints whose location was influenced by the foliation, but whether they antedate the vertical joints or not can not be told.

Lines of excessive jointing are not infrequent in the eruptives. In such places from two to four joint sets are well marked, and the joints are closely spaced, their distance apart being measured in inches rather than feet, chopping up the rock into a multitude of small blocks, and forming prominent lines of weakness in it. Often multiple faulting has taken place along these strips on one of the joint sets, grinding and slickensiding the rock surfaces. This faulting seems to be of Precambric age, and has been noted in several places, affecting both the eruptives and the gneisses. The entire rock complex along the gorge at Raquette falls (gabbroid anorthosite cut by gabbro) is remarkably shattered by multiple jointing of this sort throughout the length of the gorge, a distance of nearly 1 mile. At the lower end the sheared joints run n. 10° e., but elsewhere the trend is n. 40°-50° e., and no n. 10° e. joints appear. The trend of the gorge is clearly determined throughout by this joint set. There are also two sets of inclined joints, striking n. 50° w., one hading 20° n., the other 45° s. It is exceedingly probable that considerable faulting has taken place on the northeast joints.

Many excellent examples of the same sort are shown in the fine series of exposures along the roads in Litchfield park in the granites and granitic syenites. By the road along the north shore of Duck lake, about midway of the lake, occurs the most shattered material seen in the quadrangle. The rock is granitic syenite, cut by Morris granite. The slipping has been along a n. 65° e. joint set, so closely spaced as to form an excellent fracture cleavage, considerable secondary quartz has been deposited, and the rock rapidly weathers down to a mass of fine splinters, strongly resembling rotted wood splinters at a little distance, all due to excessive shattering, accompanied in all probability by faulting.

Faults. It is not easy to demonstrate the presence of faults in districts whose stratigraphy has not been deciphered and to definitely locate them and determine their magnitude, in such areas, is well nigh impossible. It is however known that faults are fre-

Plate 5

Near view of the steep south face of the Mt Morris spur. The cliff rises quite sheer for some 800 feet and is probably a fault scarp

quent and important structural features in the Paleozoic rocks which fringe the Adirondacks; that they most abound on the east; that on the north and south they diminish in number and magnitude going westward, and that on the west they are small and infrequent. It is also known that they are normal faults with nearly vertical hade; that many of them have throws of several hundred feet (some of from 1000 to 2000 feet); that the principal ones run north to northeast; that there are numerous cross faults running west to northwest; and that from the Paleozoics they run into the crystalline rocks with their magnitude unimpaired. A priori therefore their presence should be expected in the Adirondacks, and they should diminish in importance westward through the region.

The Long Lake quadrangle is in the mid-Adirondack region. In the Mohawk valley large faults are found considerably west of its meridian, the Little Falls fault, longitude 74° 50′, being the most westerly of the large faults there, and with an average north-northeast trend. Faulting on that trend, prolonged into the Adirondacks from Little Falls would involve the Long lake region, and some evidence of faulting would naturally be expected, though not as prominently as would be the case farther east.

Actual evidence of faulting is furnished by the slickensided character of the multiple joint surfaces previously described, but this seems to be faulting of very ancient date, and is not the common type of faulting here under consideration.

The indirect evidence for faulting in the district is twofold.

1 *Topographic.* As repeatedly urged by Kemp for the more faulted district to the east the shape of the ridge blocks, a gentle crest slope in one direction and a steep cliff face in the other, is strongly suggestive of block faulting, and indeed no other reasonable explanation suggests itself for it. Fault scarps of the sort appear in the Long Lake quadrangle. The great cliff on the south side of Mt Morris [*see* the topographic map and pl. 5] is one such, and is one of the most conspicuous examples in the whole region. The two big ridges to the southeast of Mt Morris are also of the block-faulted type [pl. 19]. But on the whole this type of ridge is not especially prominent within the quadrangle, or at least recent faulting of the sort is not suggested outside of the examples mentioned. Others of the ridges do somewhat suggest more eroded examples of the same type.

2 *Grenville belts and patches.* To explain the situation of some of the Grenville rock belts, inclosed on both sides as they are by the later eruptives, it seems necessary to assume that they lie in downfaulted troughs. They now constitute valleys with the eruptives forming the adjoining ridges, as well as underlying the Grenville at an unknown depth in the valleys. This makes a considerable and quite abrupt change in the level of the upper surface of the eruptive. Unless these are downfaulted troughs it seems necessary to assume this curiously irregular upper surface to the igneous batholite, so that the other supposition seems vastly the more probable.

The areal mapping seems to emphasize this suggestion, though the evidence has not the weight it would have in a district whose stratigraphy was well worked out. The boundary between the Follensby-Cold River Grenville and the anorthosite and syenite which adjoin it on the northeast, appears to be a fault contact, though the Grenville exposures are not frequent enough to enable exact mapping. The boundary between the Moose creek-Bog stream Grenville, and the syenite and gneisses to the north, is also suggestive of faulting. Too little is known of the relationships of the Grampus gneiss to warrant any deductions from the mapped contact between it and the Grampus Grenville.

TOPOGRAPHY

The main axis of elevation in northern New York bears south through western Clinton and Essex counties to the Marcy region, then swerves to a southwesterly trend which is continued through Hamilton county. This line forms the major axis of the Adirondack highland. From it the surface drops gently westward toward Lake Ontario and the St Lawrence; from it the surface drops more abruptly and jerkily eastward to Lake Champlain. The minor axis of elevation passes westward through Essex and southern Franklin counties, intersecting the other in the Mt Marcy region. The general highland of the northern half of the Long Lake quadrangle constitutes the western portion of this minor axis, while the entire quadrangle lies west of the major axis.

In northern Hamilton two broad valley regions cross the major axis separating the Hamilton from the Essex portion. One of these valleys is certainly and the other probably located on a belt of Grenville rocks. The lowland along the southern margin of

Looking south into Hamilton county, from a hill summit in Litchfield park, Franklin county, with Duck lake in the mid view. The line between the two counties passes through the south apex of the lake. The comparatively even sky line given by the ridge crests is well shown and the broad valley in the foreground, the pond lying at one edge is quite typical.

the Long Lake quadrangle constitutes the northern portion of the first of these lowland belts. A similar, though less conspicuous lowland belt is developed across the south center of the quadrangle, again located on the Grenville rocks, and separating the two highland areas of the quadrangle.

Peneplains. It has been elsewhere shown to be probable that, during Mesozoic time, the Adirondack region was worn down to a comparatively even surface or peneplain, which was subsequently uplifted, and that the accordant levels of the hill and ridge tops and crests observable in the southern and western Adirondacks are due to the fact that they are remnants of this old surface.[1] The uplift renewed erosion and the present broad valleys of the region were cut out, the comparatively concordant levels of their bottoms marking the new base level, and their depth below the peneplain horizon measuring the amount of uplift. Since their development there has been further uplift of the region, the old valley bottom level is no longer the stream grade, and the streams are now engaged in the task of cutting down to the new grade, in which task they have made but slight progress.

All these uplifts have somewhat tilted the old peneplain surface though the amount of tilting is but slight, and in the southern and western regions the even sky line of the ridges is everywhere notable. But on the northeast the ridge tops appear at varying altitudes and hardly suggest a peneplain surface. This is thought to be due to renewed faulting during the more recent times of uplift, giving the various fault blocks differing altitudes, and destroying their previous concordance of surface. It seems also to be true that monadnocks, or parts of the old surface which were never worn down to the general peneplain level, are larger and more abundant in the vicinity of the main axis of elevation than they are elsewhere, and this makes an additional obstacle in the way of recognition of that surface.

The probability that faulting has played some part in the production of the present topography of the district, though by no means as important a part as it has farther eastward, has already been indicated. Therefore more evidence of former peneplaination should be observable here than there. An inspection

1 N. Y. State Mus. Bul. 95, p. 423–27; Ogilvie, I. H. N. Y. State Mus. Bul. 96, p. 468–69.

of the topographic map shows that in both the northern and southern highland areas the hill summits tend to elevations of from 2600 to 2800 feet, with the Kempshall and Morris summits alone overtopping that elevation as small monadnocks [pl. 5, 6, 14]. A study of the topographic maps of the adjacent quadrangles however quickly dispels the impression that we have here a peneplain level which can be shown to extend over any considerable area. On the St Regis quadrangle, just north, but a single hill (St Regis mt, 2882 feet) exceeds 2600 feet elevation, and there are but two others which reach 2500 feet, most of the hills ranging from 1900 to 2200 feet. There is further seen a range of hills running across the quadrangle from northeast to southwest east of which lies a depressed belt, the lake belt, in which the hilltops little exceed 1800 feet, yet the rock is anorthosite, as it is in the higher range to the west. This lake belt seems a downfaulted trough, and its southward prolongation forms the northwest portion of the Long Lake quadrangle. The altitudes of the hill range are fairly concordant with those of the highlands on the Long Lake quadrangle. In both the valley levels are near 1600 feet, indicating that the dislocation of the peneplain surface by faulting dates mainly from the time of the first uplift which followed its formation.

On the Santanoni quadrangle, adjoining the Long Lake on the east, there are several peaks over 4000 feet high, the main watershed of the region appears, and we are carried at once into the high Adirondacks. There are no elevations concordant with those on the Long Lake sheet, and there are many things which suggest considerable faulting. Because of proximity to the watershed the valley levels are also higher, but seem fairly concordant, taking this into consideration.

South, on the Blue Mountain quadrangle, are many peaks with altitudes well over 3000 feet, with Blue mountain, 3759 feet, overtopping them all. There are also many lower hills which are more in accord with the general Long lake altitudes. Whether the higher hills are to be classed with Kempshall and Morris as monadnocks, in which case they would be very numerous, or whether they represent the peneplain level, dislocated out of accord with the Long lake levels, is not certain.

Topography as conditioned by the rocks. Owing to their weak resistance to erosion, in comparison with the other rocks of the region, the Grenville rocks give rise to valleys, and the main

Plate 7

The Mt Morris mass from the west showing the fairly even sky line of the ridge crests and the slight elevation of the summit knob above this level. At the right of the summit knob appears the upper part of the cliff which terminates the mountain on the southwest.

Plate 8

Mt Kempshall and the intervening ridges, from the Island House. All are of Long Lake gneiss and illustrate its topography.

The Seward range from the Island House, Long lake; the Raquette valley notch on the left, with Ampersand mountain in the far distance. All the ridges in the view are of anorthosite

valley belt of the quadrangle is a Grenville belt. Because of the greater strength of the quartzite member of the series, it gives rise to considerable hills in each of the belts, but otherwise they are low. It is quite likely, too, that the lowland along the southern margin of the sheet, and that about Round pond, is really Grenville territory. The few exposures seen in each area are of uncertain gneisses, and do not suffice to definitely determine what the prevailing underlying rock may be. Except for the lowland along the north margin of the sheet, which belongs to the lake belt and is likely due to down faulting, the main lowlands are owing to the presence of Grenville rocks and their weakness.

The hills tend to the long ridge type with their major axes trending northeast-southwest. Those which suggest faulting have a northeast pitch to their crest, and a steep, clifflike back slope on the southwest, as seen on Mt Morris and on the ridges east of Little Simons pond. Stony Creek mountain shows an approach to the same type. On the other hand the long, irregular ridge of Rock Pond and Grampus Lake mountains does not at all suggest the type, and the Kempshall mass is not even of the ridge type. There is a tendency on the part of the elevations in the gneiss country to be of the hill, rather than of the ridge type, as illustrated by Mt Kempshall and Buck mountain, while this type is practically absent in the anorthosite and syenite country [pl. 7–9].

Drainage lines. In so far as there are belts of weak Grenville rocks, the valleys so located are drainage lines, whose trend is determined by that of the Grenville belt. Moose creek, Bog stream, lower Cold river, and the Raquette between Cold river and Moose creek, are the principal streams of the quadrangle occupying Grenville valleys. In so far as the remainder of the water courses are concerned, the lines of weakness which they occupy must be structural rather than stratigraphic, hence must be lines of jointing and faulting. Hobbs has recently presented strong arguments for the belief that such lines have had predominant influence in the location of the drainage lines of New England and Eastern New York.[1] But it is difficult to apply the argument in a district where joints are found with all possible compass directions, as they are within this quadrangle. Yet, as has been pointed out, there are certain directions of more frequent, and more important

[1] Jour. Geol. 1901. 9: 469–84; Geol. Soc. Am. Bul. 1904. 15: 483–506.

jointing and it is of interest to ascertain whether those directions are also the more usual directions of the drainage channels. Since faults have not the prominence that they have to the eastward, they can not have the important effect upon the drainage that they there have.

The two prominently linear drainage lines of the quadrangle are the Long lake, and the Raquette-Upper Saranac lines. The trend of Long lake throughout its 13½ miles of length is closely n. 35° e., nearly half of the lake being on the Blue Mountain quadrangle. Above the lake the Raquette follows the same trend line for at least 2 miles more. Below the lake for a mile we have the Raquette and Cold rivers on the same line, beyond which Calkins creek follows it for 5 miles more; in other words for 21 miles this is a linear drainage line. Other lines, though shorter and less prominent, have the same trend; the line containing Rock pond, Second and Third Anthony ponds, and their inflowing creeks for one; Grampus and Handsome ponds and the main tributary to Upper Moose creek form another; the Raquette from the mouth of Moose creek to the landing below the falls is equally linear though not quite parallel, the direction being n. 45° e. This is the most prominent drainage direction in the southern half of the quadrangle. It is even more prominent to the southeastward, the Indian lake-Upper Hudson line having the same trend.

In the northern half of the quadrangle the meridional direction is the more conspicuous. The most prominent line of the sort is that followed by the Raquette river from the falls to Axton, then across to Upper Saranac lake, the valley being blocked by drift sands between the two points. The lake, 7½ miles long and trending north and south is on the same line. Follensby pond, with its inlet and outlet, and the Raquette river below as far as Tromblee's, constitutes another such line. These straight courses would all seem to be determined by lines of jointing, and likely of multiple jointing and slip faulting. It is certainly true that the meridional joint direction is the more important in the northern, and the northeast direction in the southern part of the quadrangle, and these drainage directions are in accord with this.

The east and west direction for the tributary streams is the more common one in the district, though this prominence is vastly better brought out on the Blue Mountain quadrangle than on the Long Lake. Here the line of Ampersand brook and the Raquette river

from Axton to Follensby outlet is the most important one. The Bog stream and Big brook stream have the same alinement. The northwest direction is uncommon, though it becomes the prevailing stream direction in the quadrangles to the northwest. But in these the faulted district has been left behind, and the streams seem to be consequent streams.

GLACIATION

Striae. The location and direction of the glacial striae noted within the quadrangle limits are indicated upon the accompanying map, with two additional readings just outside these limits to the west. All are found by roadsides, upon recently stripped ledges. But the larger number of the rock exposures elsewhere show glacial rounding and polish, the striae being obliterated by the weather. The fact that recently stripped exposures show them with great frequency, seems to indicate that they were abundantly produced within the district. Further, all seen are in valleys, and some of them in valleys whose trend is at right angles to the direction of ice motion. Ogilvie has urged that, in the high Adirondacks, glaciation was comparatively feeble and mainly effective upon the hilltops, the ice in the valleys being comparatively stagnant.[1] But if this be true it can only be so for a very restricted area, since the Long Lake quadrangle closely adjoins the high district, and the valleys show abundant evidence of considerable glaciation.

The 10 readings on striae shown on the map vary in direction from s. 25° w. to s. 75° w. While plainly influenced by the valley trends they harmonize well with the statements of Kemp and Ogilvie that the general direction of ice motion across the Adirondack region was a southwesterly one. Six of the 10 are in harmony with that statement. The other four, the two on the north shore of Jenkins pond, the one by Little Simons, and one of those outside the sheet, are influenced by, and have closely the trend of the valleys in which they lie. More striking instances of similar deflection are shown on the Tupper Lake quadrangle, next west, where, on stripped ledges along the railroad, readings of n. 80° w. and n. 75° w. were obtained, parallel to the trend of the Raquette valley. The general southwest direction also holds on that quadrangle, and there also striae are found numerously on recently stripped ledges.

Glacial deposits. No heavy and thick deposits of till have been noted within the quadrangle limits, nor any bulky moraines. There

1 Jour. Geol. Apr. May 1901. v. 10; N. Y. State Mus. Bul. 96, p. 470.

is however often a respectable amount of till, and many areas are at least thinly covered with morainic material. But on the whole glacial removal seems to have been in excess of glacial deposit.

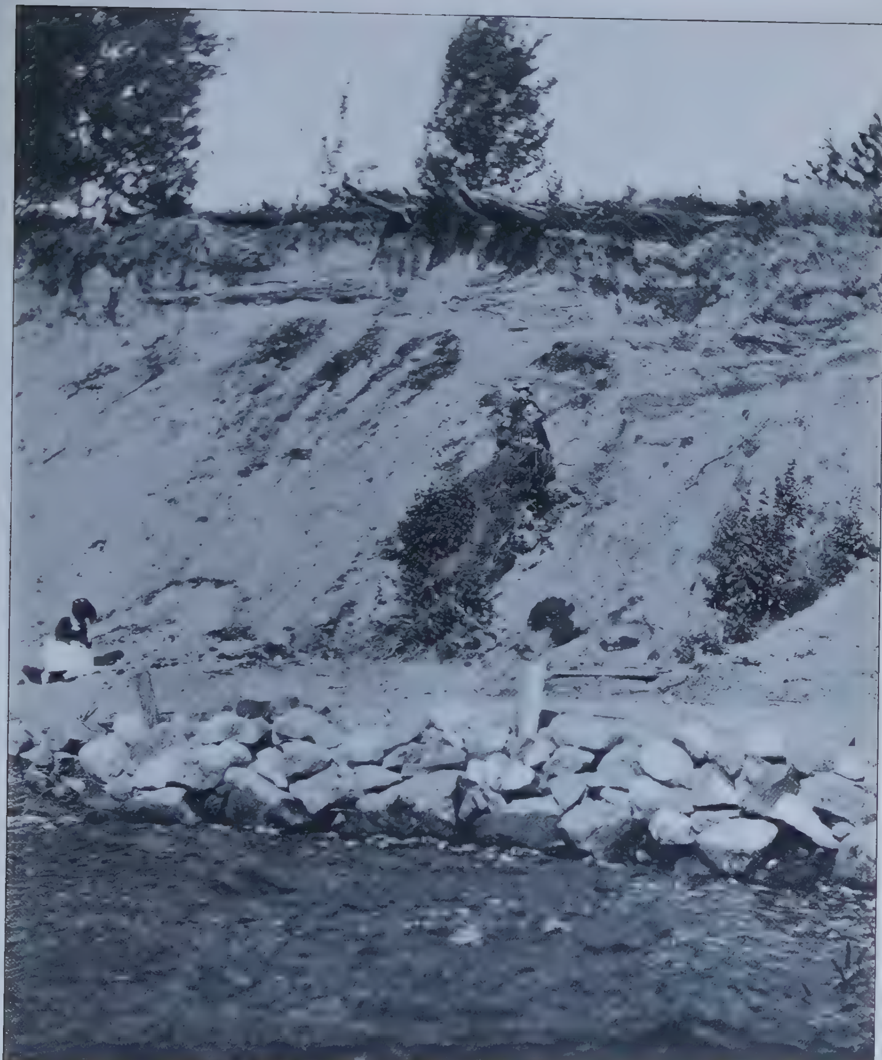
The main areas of morainic accumulation are shown on the accompanying map, though not fully, only those sufficiently extensive to render the areal mapping somewhat uncertain being shown. It may be said in general that the main valleys all have their floors banked up with drift, and that the north slopes of the ridges are apt to be similarly encumbered. The matrix of the deposits is quite sandy, or gravelly, as is usual in the Adirondacks, but they contain many large boulders, and there are often large boulder trains on the surface.

A moraine of considerable prominence runs across the northern portion of the quadrangle from Tupper lake to Axton and beyond. There is a tendency to kame development along its front, as is common in the district, and at Moody is a notable instance of the sort [*see* map and pl. 10]. The waves of the lake have eaten away its end producing a 20 foot sand bluff, showing cross-bedded sands with a coarse gravel streak near the top. A short distance back it runs up to a conical summit, 150 feet above the lake. Yet further east it runs up against the moraine, two flat terraces appearing during this rise, their surface covered with gravel and occasional cobbles, but no large boulders. This fringe of water-laid material borders the moraine on the south for a considerable distance. About Tupper Lake Junction is another development of sands, and Little Wolf pond, whose southern shore appears at the north margin of the sheet, is held up at the south by these sands. A great sand and gravel terrace, with occasional large boulders extends up the Cold river valley, banked up against the anorthosite hills beyond, and seems a true kame terrace.

The broad Grenville valley belt of the quadrangle is rather heavily moraine covered. The local character of the drift is emphasized here since Grenville boulders abound, but elsewhere are scarce or absent, so that they can be used rather confidently for areal mapping. Throughout the gneissic area also the low grounds and the gentle hill slopes are moraine covered. The accumulations are in general not large, nor do they tend prominently to the ridge type. There is no indication within the quadrangle limits of any protracted pause during the ice withdrawal.

Numerous cuts in till are shown along many of the roads, espe-

Plate 10



Bluff produced in kame sand ridge at Moody, Tupper Lake shore. Cross-bedding shows midway at the top.

cially in the northern half of the quadrangle. It is quite sandy or gravelly in character, and has been much used for surfacing the roads, answering fairly well for that purpose in many places.

Valley plains and pitted plains. In the district north of the Long Lake quadrangle there is evidence of pause in the ice retreat, in the considerable moraine which runs west from Placid to Saranac, and thence on northwest to Lake Clear and Brandon. Running southwest from this is a great sand-filled valley, commencing at Lake Clear and ending at Tupper Lake Junction. The general character of its surface is well shown on the St Regis quadrangle topographic map. A number of small rock knobs project above it, and the railway cuts west of Saranac Inn station well illustrate the general way in which these knobs are wholly or partly drowned in the sand. The material is mostly even grained sand of medium grain. There is little gravel in it and no clay.

In addition to the rock knobs the surface shows diversity of another sort, small oval or circular depressions below the general surface which are in some cases dry and in others occupied by small ponds. There is a notable collection of these between Upper Saranac lake and Lake Clear, and thence northward to Upper St Regis lake and beyond. It is exceptional that a topographic map brings out the feature better.

The general area is also noteworthy in the number of lakes and ponds. There are about 150 of these in the St Regis quadrangle, in all probability a greater number than is found on any other of the Adirondack map sheets. And they are mainly massed along this sand belt and occupy depressions in its surface. The upper end of Upper Saranac lake has these sands for its shores, and the abundant and good sized ponds to the westward have also sandy shores except for the occasional rock knobs protruding through the sand. The general level of the deposit falls to the southwest though the fall is only slight, from 12 to 18 inches to the mile. The sand must have been deposited from a current which ran across the region to the Raquette just below Raquette pond. In order to account for this flow we must presume that the present outflow through the Saranac river was blocked, and it would seem that it must have been blocked by ice which lay near at hand. The depressions in the sand are of the kettle hole type, and the fact that the larger ponds were not filled by the sand suggests that they were occupied by stagnant and slowly melting ice tongues

which persisted until after the melting back of the main ice front withdrew the water supply from this particular channel. The subsequent disappearance of the ice tongues left the basins occupied by the present ponds. The small kettle holes were likely formed in the same way, small unmelted ice masses being left during the general retreat of the front, covered with sand and subsequently slowly melting away. The Upper Saranac lake valley was likely occupied by the largest tongue of all, and the sands were washed upon its north end but were otherwise kept out of the valley. If this be the true explanation of the character of the district it follows that the ice disappeared from it by melting back toward the northeast and that, for a time, the Raquette river carried the upper Saranac drainage.

There is another and parallel line of identically the same nature on the St Regis quadrangle, extending from the Forestmere lakes down to Bay pond and beyond, with a tributary line coming into it from the north at Brandon. The sands are similar and the surface characters identical. The writer is not familiar with the district to the west and does not know whether a connection with the Raquette drainage can be traced or not. The flow may have been down the St Regis.

There are two small sand-filled channels, one wholly and one partly on the Long lake sheet. The former extends from Coreys to Axton, the route of the old Indian carry. The material is mainly sand though there are a few gravel streaks. A few surface boulders are to be seen, but very few. The surface partakes somewhat of the kame character and this was likely a channel of water discharge only during the time that the ice was retreating back over it. It is this sand filling which prevents the water of Upper Saranac lake from coming south to the Raquette river, to which drainage it properly belongs, and sends it through the modern channel, over the rock ledge at the Saranac Club (Bartletts carry). The other channel comes down to the Raquette river at the oxbow 1 mile below Tromblee's (not the Oxbow further downstream) and takes off from Upper Saranac lake at Gilpin bay. It seems also a local channel, used for a short time after the abandonment of the previous one, and before the ice had withdrawn to the north of Upper Saranac lake, opening up the great channel decribed previously.

Topography as modified by glacial erosion. The all pervading effect of glacial wear in the region was the rounding off, smoothing and polishing of the rock knobs, large and small [pl. 1–3]. Except

Plate 11

Stony Creek mountain from Axton, looking east northeast. Distance to the summit 3¼ miles. The mountain is not of the typical ridge type though it approximates it. It broadens out on the southwest and sends out two spurs with a deep amphitheater between.

Plate 12

Main fall in the gorge at Raquette falls. The rock is the border, gabbroid phase of the anorthosite and is excessively jointed and sheared

in a few protected situations all previously weathered rock was worn away, and the present day surfaces are of rock which is fresh except for the slight amount of postglacial weathering. The ice was thickest over the valleys, whose sides were notably smoothed and whose bottoms may have been deepened, though no demonstrative evidence of this has been noted. That the valleys deflected the direction of the ice movement in its basal portions to parallelism with their trend, has already been shown.

The pronounced topographic effects produced in lofty mountains by great ice streams, as many believe, are not to be seen in the region, unless to a very trifling extent. There has been some local sapping of cliffs by bergschrund action, and some tendency to the production of amphitheaters and cirques on the higher ridges. Seward pond, midway on the east margin of the quadrangle, seems a small cirque pond, but is the only sample of the kind within the quadrangle. There are however a dozen of the type in the more lofty and hilly Santanoni quadrangle next east. The two amphitheaters on the south face of Stony Creek mountain seem due to the same sort of plucking action though no basin was dug out by the ice at the foot of the slope [pl. 11]. Some of the lower level ponds may occupy rock basins dug out by the ice, though there is no evidence at hand that this is the case. In the case of the larger lakes it is quite possible that the ice may have done some excavation on their beds. Long lake trends with the ice motion and may be a rock basin dug out by the ice. But it seems equally well accounted for on the supposition that its drainage went out to the east in preglacial times, and that drift filling in the valley east of Long lake blocked the channel and sent the water over the preglacial col at Raquette falls. Certainly the greater number of the ponds of the quadrangle, both large and small, occupy hollows in the moraine or overwash sand plain surfaces, or else drift-blocked hollows in the partly drift-filled preglacial valleys. The amount of drift deposited in the valleys is considerable; not so much but that frequent rock knobs protrude above it, but sufficient to everywhere hide the rock floor, and sufficiently variable in amount to give rise to many ponds.

Drainage modifications. The entire area of the Long Lake quadrangle drains into the Raquette river, except for a small district in the northeast corner, draining into the Saranac, and a somewhat larger one on the southeast, which sends its water to the Hudson.

Except locally, the present stream valleys were also preglacial stream valleys, and the principal modifications in the drainage produced by the ice, in addition to the formation of lakes, were in shifting the divides. A moment's inspection of the topographic map suffices to show that many of the divides thereon are of the most trivial character, and are unstable. A drift-filled valley less than a mile long is all that separates Upper Saranac lake and Stony Creek pond, whose water level is 26 feet lower and which outlets by a sluggish stream into the Raquette river just above Axton. The preglacial drainage here would seem most likely to be that of a west-flowing stream in the Ampersand brook and Raquette valleys, with a tributary from the south in the present Raquette valley whose source was at Raquette falls, and another tributary from the north in the Upper Saranac lake valley. The Raquette has been a rapidly aggrading stream from below Raquette falls to Tupper lake, but shows rapids and falls a few miles below where it is out of its old channel.

The divide between Long lake and Round pond is less than 20 feet above the water level of the former and is a low drift divide. The waters of Catlin lake are 33 feet below those of Long lake, and from it there is a modern water route to the Hudson. There is similarly a valley across to the Hudson drainage commencing near Long Lake village, on the Blue Mountain quadrangle, which is a drift-blocked channel, though with a greater drift altitude than in the previous case. It would seem that one or the other of these valleys was the outlet for the preglacial drainage of the Long lake valley, above it the water flowing north and below it flowing south, the divide being at Raquette falls; or in other words the preglacial divide between the Hudson and Raquette waters was here. Abundant similar examples of modern divides of the most trivial character and composed of glacial drift can be seen on the neighboring quadrangles.

The immediate district is up near the main watershed of the region. Lower down in their courses the main streams are out of their preglacial channels here and there and are held up by the rock barriers developed in these new courses. Owing to the slow rate of progress in cutting through these the headwater portions of the drainage channels have slight fall and little cutting power, and divide shifting must in the main be delayed until these lower portions of the streams have deepened their channels.

Lower arm of Stony Creek pond; a pond occupying a depression at one side of a glacial stream sand deposit. Stony Creek mountain beyond

Plate 14

Jenkins pond (Lake Madeleine), Litchfield park, a long sinuous pond occupying a narrow preglacial valley and held up by morainic deposits at its west end. View taken from the anorthosite knob to the northeast

From the present main elevated axis the steeper and shorter stream slopes are those toward the east into the Champlain valley. There is hence a tendency on the part of the east-flowing streams to push their head waters across the divide and establish a new stream divide to the west of the elevation axis. Two great valleys had been pushed through the axis in preglacial times, on belts of weak Grenville rocks and, as stated above, much of the present Raquette drainage above Raquette falls seems then to have gone out to the eastward, and has been turned back to a westerly drainage system by uneven glacial deposits. The Saranac is the only present day stream going to Lake Champlain which crosses the main axis. It is quite certain that in the future others will do the same thing, unless again retarded by further uplift on the east.

Postglacial topographic changes in the region have been comparatively slight. A slow uplift of the district has been in progress so that the drainage has had a changing base level throughout the time. The streams, where out of their old courses, or where across old cols, have developed falls and rapids with gorges below, but the rocks are mostly very resistant, even the largest of the streams are of only moderate size, and toward their head waters they are often filtered clear of sediment by passing through lakes. These things all combine to make the amount of postglacial cutting comparatively slight. Locally the streams have aggraded their valleys, sometimes because of a reversal of direction, at others because of being turned out of their old valleys locally by drift obstruction. Much of the Raquette valley within the quadrangle is of this character. It is a meandering stream on a wide valley floor, bordered by mud banks which fall off to swamps away from the stream, and with frequent cut-off meanders in all stages of filling [pl. 20].

A considerable amount of lake filling has also been done, as a moment's inspection of the map will show. The present Tupper Lake reservoir is simply the reexcavated portion of a former pond which had been entirely converted into swamp. It is an interesting locality in that there is a well preserved old shore line on the north side marking a former water stage 10 feet above the present. This shore is marked by a boulder accumulation, concentrated there by the washing away of the associated finer material by the action of the waves.

Even the largest of the lakes are not sufficiently large to permit

of the production of waves powerful enough to have an important shaping action upon their shores. Bare rock ledges are a feature of the shores of most of them. Elsewhere they are largely of boulders washed out of the moraines, upon which the waves have a little more effect than upon the ledges. Little deltas appear at some of the brook mouths. Where kame or valley sands form the shores rapid cutting is in progress and rapid shallowing as well. One prominent sand spit has been developed on the Long lake shore in the lee of Camp island [pl. 15, 16], with others of less prominence to the south.

ECONOMIC GEOLOGY

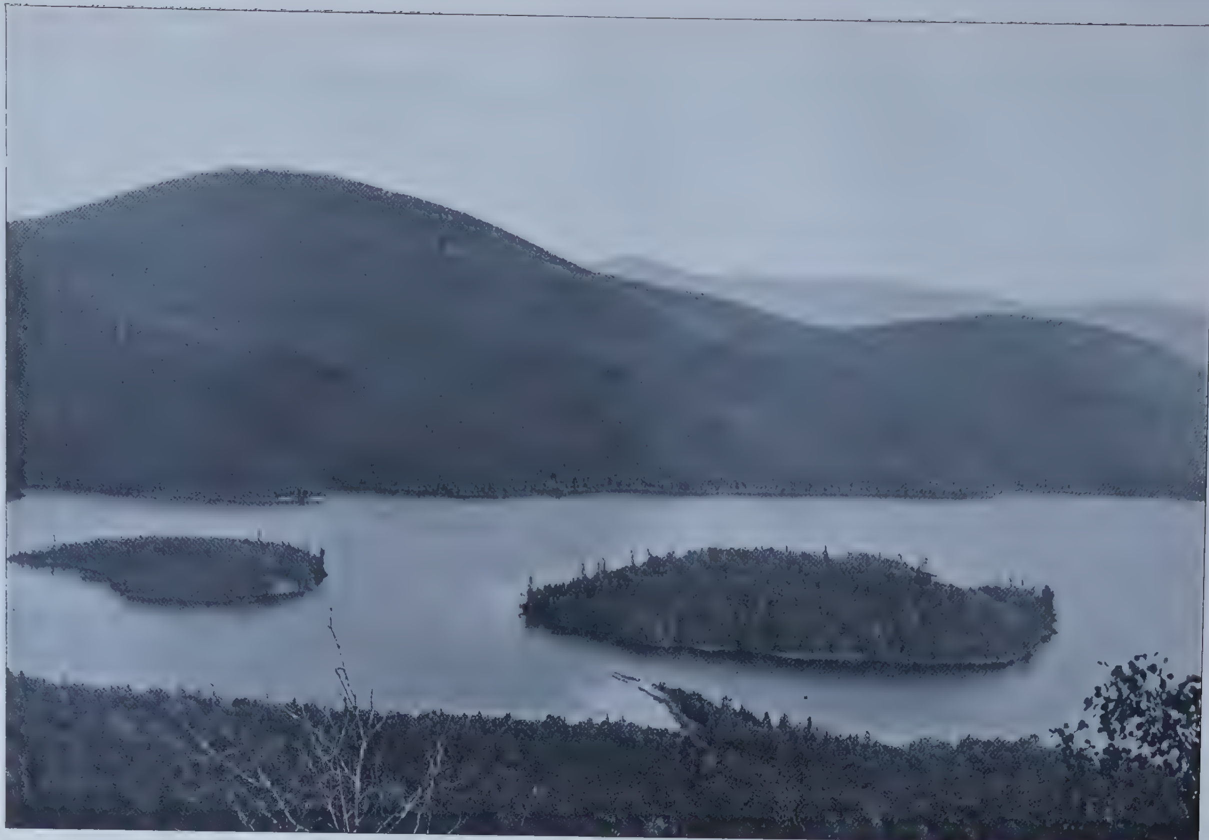
If the district was, or was ever likely to become, a thickly settled one there are some things that might have considerable economic importance; as it is there is little of that nature. Aside from its iron ore the Adirondack region shows little or nothing in the way of metalliferous wealth. Within the area of the quadrangle no deposits of iron ore were seen, nor have any ever been exploited, so far as could be discovered, though such are known from all of the adjacent quadrangles, of which the titaniferous ores about Lake Sanford within the Santanoni quadrangle are much the most important.[1] These ores are found in the anorthosite and result from its differentiation, but there are none such found within the anorthosite area of the Long Lake quadrangle except possibly of such minor size that they have been missed during the present survey. Nor have magnetite ore bodies been noted within the areas of gneiss and syenite, in either of which they might occur. In the district between Raquette Falls and Follensby pond there is some local compass variation, though it is hardly indicative of any large ore body.

There is considerable graphite in disseminated form in the Grenville rocks, both in the sediments and locally in the igneous rocks, as is usual in the formation, but nothing was seen which would indicate that it is anywhere present in sufficient quantity to form a workable deposit.

Building stone. In the granite, syenite and anorthosite areas of the quadrangle there is an inexhaustible supply of building stone of fair quality, and much of the granitic Long lake gneiss can also be used for structural purposes. It is not likely that any of the stone is of such high grade that quarrying operations on a large scale for export would be advisable, but there is an ample supply of material

[1] Kemp, J. F. U. S. Geol. Sur. 19th An. Rep't, pt 3, p. 409–19.

Plate 15



Looking across Long lake from near the summit of Buck mountain; showing Mt Kempshall and Blueberry mountain, the Camp islands and the sand spit running out from the west shore toward the southerly end of the islands; the Sabattis range in the distance

Plate 16

Enlarged view of part of plate 15 to better show the sand spit

for all possible local use. Perhaps the best material of all is the red, granitic syenite, the color of which is pleasing, and not susceptible to the change which the green syenite experiences. The handsome lodge and gate at Litchfield park are constructed of this material, and a prettier red granite would be hard to find [pl. 17]. The material was obtained from boulders within the park, and close at hand, but there is a plentiful supply exposed in places to the east. In all respects except that of color much of the syenite is an equally good building material, and its original greenish shade is a pleasing color to many; but its rather rapid change to brownish tints on exposure to the air is a drawback. It has been used for foundation and other work at Tupper Lake to a considerable extent and for durability and strength is unexcelled. The color change is the only drawback to its use for more pretentious work.

The anorthosite is also a strong, durable stone serving well for all rough purposes. The coarser varieties have had considerable use in the region in the construction of rustic mantels and chimneys, and the stone is very handsome when so used. None of it possesses the property of iridescence in a high degree but much of it has somewhat of the character, and this enhances its effectiveness for such use.

Road metal. The best stone for roadmaking in the district is the basic variety of the syenite. This has been considerably quarried at Tupper lake and used locally upon the roads, and also been exported to some extent [pl. 18]. It is hard and tough and has excellent binding power, being equal to the best trap rock in these qualities. The more feldspathic syenite makes nearly as good road metal as the more basic variety. The more gabbroic anorthosite would also make a good road rock, though it has not been used locally because of the plentiful supply of the syenite.

Some of the roads of the quadrangle have been surfaced with sandy gravel dug from the moraine along the roadsides. Where carefully selected it makes a very good road provided its usage is not too hard. In many cases however it has not been well selected, and where there is heavy teaming it does not prove very durable.

PETROGRAPHY OF THE ROCKS

While the general petrography of many of the rocks of the quadrangle has been given by Kemp, Smyth and the writer in their various reports to the State Geologist, the work is far from being exhaustive, and some more exact work on certain rocks seemed desirable.

Grenville rocks. The quartzose rocks are the only members of the Grenville series sufficiently well shown within the quadrangle to repay careful study. In general their mineralogy is comparatively simple, as they are made up of quartz, feldspar, pyroxene and phlogopite mica in varying amounts. Small amounts of various accessory minerals are also present but seldom in sufficient quantity to affect the general statement. In general there is little difficulty in distinguishing the quartz and feldspar under the microscope, and mostly the feldspar admits of fairly accurate microscopic determination. So far as they are concerned therefore, the rocks admit of reasonably accurate microscopic analysis. But the pyroxene and mica are minerals of very varying composition, and as a first step it was desirable to have analyses of them available, for use in calculating the results of the microscopic rock analyses. For a pyroxene analysis a rock was selected free from mica, and with only accessory titanite and zircon present in addition to the quartz, feldspar and pyroxene. The titanite was fairly abundant and occurred included in all the three constituent minerals, so that it was impossible to wholly separate it from the pyroxene, but with this exception an absolutely clean pyroxene powder was obtained with Thoulet solution. Since titanites do not vary widely from their theoretical composition, it seemed that, by using the amount of TiO_2 obtained in the analysis as a base for calculating out the titanite, the remainder must closely represent the composition of the pyroxene.

Analysis of pyroxene from quartz-pyroxene gneiss (3-C-4) 1 mile east of Grampus lake

	Analysis	Titanite	Pyroxene	To 100%
SiO_2	52.87	1.43	51.44	54.20
Al_2O_3	3.01	....	3.01	3.17
Fe_2O_3	1.76	....	1.76	1.86
FeO	6.21	....	6.21	6.54
MgO	17.68	....	17.68	18.63
CaO	14.47	1.36	13.11	13.81
Na_2O	0.98	....	0.98	1.03
K_2O	0.29	....	0.29	0.31
MnO_2	0.32	....	0.32	0.34
H_2O	0.10	....	0.10	0.11
TiO_2	1.88	1.88	....	....
	99.57	4.67	94.90	100.00

[1] E. W. Morley, analyst.

Plate 17

Gate and lodge at Litchfield park, constructed of red, granitic syenite obtained near by

Plate 18

Road metal quarry in augite syenite, at Tupper Lake village. The rock is more basic and gneissoid than usual, and rather excessively jointed, those in the view belonging to the n. 50 w. series, the most prominent and regular one just here. Rude and irregular horizontal joints are also to be seen.

This pyroxene is highly exceptional in its lime-magnesia ratio, so much so that it is unsafe to assume, as was hoped might be done, that it is representative of the pyroxenes of these rocks. Since however this assumption involves less uncertainty than the assumption that some other pyroxene may be representative, or the assumption than no pyroxene is representative, it is made use of in the following calculations. It may well be that the pyroxenes formed in highly metamorphosed sediments tend to show a different lime-magnesia ratio from those of igneous rocks, in correspondence with the well known differences in this ratio exhibited by the two classes of rocks.

This especial pyroxene is of rather dark green color, as evinced also by the iron percentage shown in the analysis. But the pyroxenes of these Grenville gneisses are by no means uniform in this regard, being often white, or light green. It is however thought that this is simply due to variations of comparatively small range in the iron content, sufficiently small to form a matter of slight importance in the composition of the whole rock.

Microscopic analysis of the section of the rock by Rosiwal's method gave the result indicated in the following table. Only the

	Units measured	Sp. Gr.		Units by weight		% weight
Quartz	1506	x 2.65	=	3991	=	55.50
Feldspar	664	x 2.6	=	1726	=	24.01
Pyroxene	379	x 3.3	=	1251	=	17.40
Titanite	51	x 3.5	=	178	=	2.47
Zircon	10	x 4.5	=	45	=	0.62
Total	2610			7191		100.00

five minerals mentioned were present in the slide and the two latter in but slight quantity. The larger part of the feldspar showed plagioclase twinning with maximum extinction angles of 12°, indicating either an acid andesin, about $Ab_2\ An_1$, or else albite, in all probability the former. There was also a small amount of untwinned feldspar which was perhaps orthoclase. As a check on the calculation and an aid in making more certain the character of the feldspar, Professor Morley determined the silica and alkalis in the rock, as follows: SiO_2, 80.89%; Na_2O, 1.81%; K_2O, 0.44%.

Then the composition of the rock was calculated, first determining the pyroxene from its known composition, using the remainder of the alkalis for the orthoclase and albite determination, and the silica residue forming the quartz. The feldspar deficiency on this basis made it certain that the feldspar was not albite, hence enough

anorthite was assumed to form $Ab_2 An_1$ with the albite. The result is given in the table, which agrees closely with the microscopic analysis, though the silica is a little higher, and the alumina cor-

Chemical composition of quartz-pyroxene gneiss, calculated from mode and partial analysis

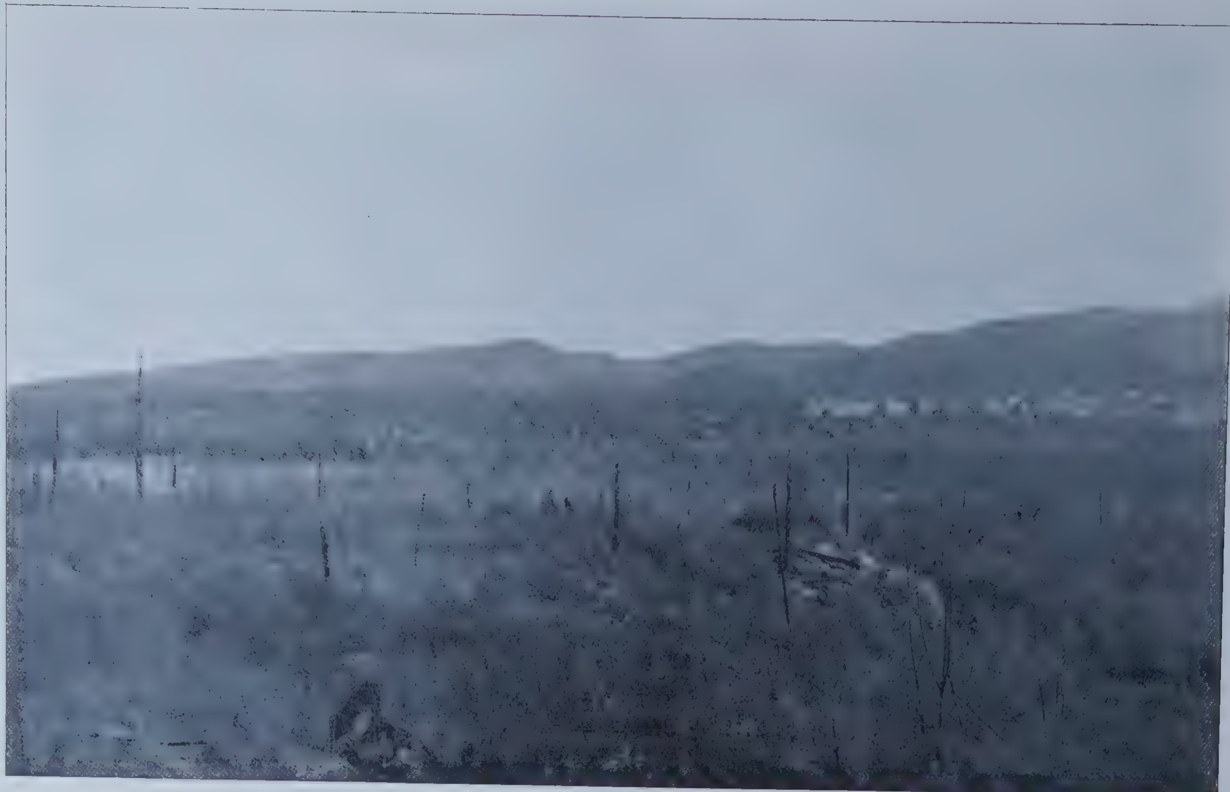
	Qz.	Orth.	Alb.	Anor.	Pyr.	Tit.	Zir.	Total
SiO_2	56.69	1.47	9.47	2.96	9.43	0.78	0.20	80.00
Al_2O_3		0.42	2.69	2.53	0.55			6.19
Fe_2O_3					0.32			0.32
FeO					1.14			1.14
MgO					3.25			3.25
CaO				1.38	2.41	0.69		4.48
Na_2O			1.63		0.18			1.81
K_2O		0.39			0.05			0.44
MnO_2					0.06			0.06
TiO_2						0.99		0.99
ZrO_2							0.42	0.42
Total	56.69	2.28	13.79	6.87	17.39	2.46	0.62	100.00

respondingly lower than in that. The more probable cause for the difference is a failure in all cases to distinguish between quartz and feldspar in the slide. But the totals would be but slightly affected, and the character of the rock as surely indicated in the one case as in the other.

The analysis shows a distinctively sedimentary rock, a metamorphosed sandstone which was somewhat shaly, and somewhat calcareous. The low alumina, comparatively high lime and magnesia and low alkalis show a wide discrepancy when compared with any igneous rock of similar silica percentage. There is however close agreement with the composition of such a sandstone as indicated. While such origin had been inferred from the appearance of the rock in the field, and in thin section, it seems to be put beyond reasonable doubt by the analysis.

In the purer varieties of these rocks, such as are found for example on the hill in the extreme southeast corner of the quadrangle, where they are exposed in large thickness, the rock is entirely composed of quartz and white pyroxene, with here and there a little bit of graphite. The rock is foliated and the thin section is certainly richer in pyroxene than the main rock, and therefore not adapted to analysis. But the mineralogic make-up is such that there is no question as to the character of the rock. Its silica percentage would be somewhat higher than in the previous case, not far from 85%, the remainder being mostly lime and magnesia.

Plate 19



Looking southeast across the Raquette valley from a point near Tupper Lake village. On the right is the east spur of Mt Morris while in the center are seen the two great, northeasterly trending ridges which lie between Mt Morris and Follensby pond. These break down in steep cliffs at their south ends, suggesting faulting.

A slightly different, though yet more silicious rock is a quartz gneiss from the small Grenville area lying between Long lake and Pickwacket pond. It is a quartz, feldspar, phlogopite rock, with zircon as the only observed accessory mineral. The feldspar is so altered as to unfit the rock for chemical analysis, but still admits of accurate microscopic determination. Part of it is oligoclase, about $Ab_2\ An_1$, and the remainder seems orthoclase, at least it is untwinned. With no analysis of the phlogopite available it is assumed to have the composition of the phlogopite from Edwards, N. Y.[1] With these assumptions the microscopic analysis yields the following result (2-H-1).

	Units measured	Sp. Gr.		Units by weight		% weight
Quartz	2060	x 2.65	=	5459	=	79.13
Feldspar	326	x 2.64	=	861	=	12.48
Phlogopite	198	x 2.85	=	564	=	8.18
Zircon	3	x 4.5	=	14	=	0.21
Total	2587			6898		100.00

	Qz.	Alb.	Anor.	Phlog.	Zir.	Total
SiO_2	79.13	6.48	1.34	3.91	0.07	90.93
Al_2O_3	......	1.80	1.12	0.95	......	3.87
FeO	......	......	......	0.03	......	0.03
MgO	......	......	......	2.52	......	2.52
CaO	......	......	0.66	......	......	0.66
Na_2O	......	1.08	......	0.03	......	1.11
K_2O	......	......	......	0.74	......	0.74
ZrO_2	......	......	......	......	0.14	0.14
Total	79.13	9.36	3.12	8.18	0.21	100.00

It is quite possible that 20% or less of the feldspar is orthoclase, which would affect the soda-potash ratio perceptibly and the silica-alumina ratio slightly. The composition of the phlogopite may also vary somewhat from that assumed, and is likely to in the iron content more especially. While these uncertainties considerably affect the calculation when regarded as an exact rock analysis, they would affect it in such slight manner, from the standpoint of the general rock character, that it may be regarded as quite certain that we are dealing with a metamorphosed sandstone, slightly aluminous and slightly calcareous, but otherwise entirely normal.

Associated with the quartz gneisses about Lake Catlin is a much less quartzose rock which is quite micaceous. The thin section

1 Dana. Syst. Min. Ed. 6, p. 633, no. 8.

showed it to have similar mineralogy, quartz, feldspar, pyroxene, mica, zircon, titanite, graphite and apatite being present. The pyroxene is white instead of green and probably differs considerably from that previously discussed and analyzed. The mica is unquestionable phlogopite. Some of the feldspar, about 20%, was badly altered, showed no sign of twinning, and was assumed to be orthoclase. The remainder was twinned plagioclase with 12° maximum extinction angle, and is regarded as andesin, $Ab_2 An_1$, though it is possible that it may be albite. The analysis is therefore some-

Mode of quartz-pyroxene-phlogopite gneiss (1-L-3-a)

	Units measured	Sp. Gr.		Units by weight		% weight
Quartz	699	x 2.65	=	1852	=	30.22
Feldspar	420	x 2.64	=	1109	=	18.10
Pyroxene	642	x 3.3	=	2119	=	34.56
Phlogopite	347	x 2.85	=	989	=	16.13
Titanite	10	x 3.5	=	35	=	0.57
Zircon	4	x 4.5	=	18	=	0.29
Apatite	2	x 3.2	=	6	=	0.10
Graphite	1	x 2.4	=	2	=	0.03
Total	2125			6130		100.00

Composition calculated from mode

	Qz.	Pyrox.	Phlog.	Orth.	Alb.	Anor.	Tit.	Zir. & Ap.	Total
SiO_2	30.22	18.75	7.71	2.34	6.67	2.12	0.19	0.09	68.00
Al_2O_3	......	1.07	1.87	0.65	1.84	1.74	......	....	7.17
Fe_2O_3	......	0.65	......	......	......	......	......	....	0.65
FeO	......	2.25	0.05	......	......	......	......	....	2.30
MgO	......	6.48	4.97	......	......	......	......	....	11.45
CaO	......	4.80	......	......	......	0.97	0.16	0.06	5.99
Na_2O	......	0.35	0.08	......	1.14	......	......	....	1.57
K_2O	......	0.10	1.45	0.64	......	......	......	....	2.19
MnO_2	......	0.11	......	......	......	......	......	....	0.11
TiO_2	......	......	......	......	......	......	0.22	....	0.22
ZrO_2	......	......	......	......	......	......	......	0.20	0.20
P_2O_5	......	......	......	......	......	......	......	0.03	0.03
Total	30.22	34.56	16.13	3.63	9.65	4.83	0.57	0.38	99.97

what uncertain and its result is of itself pretty good evidence that the pyroxene is of quite different character from that analyzed and used in the calculation. The lime-magnesia ratio seems clearly quite erroneous. If the lime and magnesia percentages in the pyroxene calculation are reversed, bringing it more closely into line with the composition of ordinary diopside, this anomaly disappears.

Plate 20

Looking across the main channel of the Raquette river toward Mt Seward. View taken 2 miles west of Axton, looking up one of the backset sloughs which marks the position of a former oxbow, and which is seen separated from the main channel by the log boom.

As so modified the analysis falls closely into line with the preceding, though representing a much more impure sandstone, somewhat more shaly, and much more calcareous than the more quartzose rocks. It seems quite clearly a member of the same group.

Just north of the Bog stream, near the west edge of the quadrangle, quartz, pyroxene, feldspar gneisses occur which appear less distinctly like sediments in the field, and have somewhat the look of the ordinary gneisses. But portions of the mass are excessively quartzose, and in thin section all resemble the Grenville quartzites just described. The slide of one of the more quartzose portions shows a quartz, feldspar, pyroxene rock with small amounts of titanite, magnetite, apatite and zircon. Phlogopite is lacking, and the rock is firmer, more glassy looking and less granular than the usual quartzites. The microscopic analysis however shows a close relationship.

Mode of quartzose (Grenville) gneiss (6-B-2-a)

	Units measured	Sp. Gr.		Units by weight		% weight
Quartz	2151	x 2.65	=	5700	=	65.78
Feldspar	775	x 2.65	=	2053	=	23.69
Pyroxene	230	x 3.3	=	805	=	9.29
Titanite	16	x 3.5	=	56	=	0.65
Magnetite	7	x 5.25	=	37	=	0.42
Apatite	2	x 3.2	=	6	=	0.07
Zircon	2	x 4.5	=	9	=	0.10
Total	3183			8666		100.00

Composition calculated from mode

	Qz.	Orth.	Alb.	Anor.	Pyrox.	Tit.	Mag.	Zir. & Ap.	Total
SiO_2	65.78	2.38	8.28	3.45	5.04	0.20		0.03	85.18
Al_2O_3		0.65	2.31	2.94	0.30				6.20
Fe_2O_3					0.17		0.28		0.45
FeO					0.62		0.14		0.76
MgO					1.73				1.73
CaO				1.61	1.28	0.19		0.04	3.12
Na_2O			1.41		0.09				1.50
K_2O		0.66			0.03				0.69
MnO_2					0.03				0.03
TiO_2						0.26			0.26
ZrO_2								0.07	0.07
P_2O_5								0.02	0.02
Total	65.78	3.69	12.00	8.00	9.29	0.65	0.42	0.16	100.01

As usual some uncertainties have a vitiating effect on the calculation. The pyroxene may, or may not be like the one analyzed. If not the lime-magnesia ratio would be altered, though the change would be slight. Most of the feldspar is twinned, though 15% lacks this feature. This has been calculated as orthoclase though it may not be. The remainder shows a maximum extinction of 16°. This is the angle for both albite and andesin ($Ab_3 An_2$) but this is held with reasonable certainty to be the latter since Becke's method shows it to have the same refractive index as the quartz. Except for a possible slight increase in lime and corresponding decrease in magnesia therefore this must give a very close approximation to the actual composition of the rock. It harmonizes well with the preceding analyses and again indicates a somewhat impure sandstone, a little more aluminous and a little less calcareous than they.

Igneous rocks. *Granite.* No analyses of the Adirondack granites have been published, so far as the writer is aware. The Morris granite is of a distinct and simple type, with definitely established age relations to the other intrusives, and an accurate analysis of it seemed highly desirable. It is mainly a quartz-microperthite rock, with accessory plagioclase, hornblende (usually chloritized), magnetite, titanite and zircon, and lends itself readily to microscopic analysis. Since however the character of the feldspar can not be precisely determined microscopically an analysis was necessary to establish this. The hornblende has been thoroughly altered to

Mode of Morris granite, fine grained type (15-A-3)

	Units measured		Sp. Gr.		Units by weight		% weight
Quartz	996	x	2.65	=	2639	=	34.57
Microperthite	1804	x	2.6	=	4690	=	61.74
Plagioclase	20	x	2.63	=	153	=	2.01
Hornblende	27	x	3.2	=	86	=	1.13
Magnetite	5	x	5.25	=	26	=	0.34
Zircon	3	x	4.5	=	13	=	0.18
Titanite	1	x	3.5	=	3	=	0.03
Total	2856				7610		100.00

chlorite and small flecks of this mineral are frequent in the feldspar, and are too small to measure accurately, so that the hornblende should more properly read "chlorite" and its amount is certainly

considerably too small. The amount of zircon is probably too large, and the slide does not seem to show quite the normal amount of magnetite. The plagioclase is in minute grains and is difficult of exact determination though it seems oligoclase.

Chemical composition and norm of Morris granite (15-A-3)[1]

	Chem. comp.	Mol. ratio	Or.	Ab.	An.	Cor.	Hy.	Mt.	Qz.
SiO_2	76.41	1.273	.276	.324	.028		.012		.633
Al_2O_3	12.41	.122	.046	.054	.014	.008			
Fe_2O_3	1.01	.006						.006	
FeO	0.50	.007					.001	.006	
MgO	0.46	.011					.011		
CaO	0.78	.014			.014				
Na_2O	3.34	.054		.054					
K_2O	4.33	.046	.046						
H_2O+	0.34								
H_2O-	0.13								
TiO_2	0.03								
ZrO_2	0.02								
F	0.01								
S	0.01								
MnO	0.06								
Total	99.84		.046	.054	.014	.008	.012	.006	.633

Or.	25.58	96.34
Ab.	28.30	
An.	3.89	
Co.	0.82	
Qz.	37.95	
Hy.	1.23	2.70
Mt.	1.39	
Ti.	0.08	
Rest	0.60	
Total	99.84	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{96.34}{2.70} = 35.7 = 1$, persalane

Order, $\frac{Q}{F} = \frac{37.95}{57.77} = 0.65 = 3$, columbare

Rang, $\frac{Na_2O' + K_2O'}{CaO'} = \frac{100}{14} = 7.1 = 1$ alaskase

Subrang, $\frac{K_2O'}{Na_2O'} = \frac{46}{54} = .85 = 3$, alaskose

In the new classification of igneous rocks this granite would be called an alaskose. It is however very near the border between orders 3 and 4, so that a comparatively slight increase in feldspar at the expense of quartz would put it into the liparose division. The norm differs from the mode slightly in the quartz-feldspar percentages. A considerable portion of the magnetite of the norm belongs in the chlorite of the mode and with this would go the slight excess of alumina which appears as corundum in the norm. The hypersthene, corundum, and excess of magnetite of the norm

[1] E. W. Morley, analyst. P_2O_5, BaO and Cl absent.

would give an amount of chlorite considerably in excess of the chloritized hornblende of the mode, which has already been accounted for. The feldspar percentage should be correspondingly decreased. Even then the difference between the quartz feldspar ratio in the norm and mode, .65 in one case and .56 in the other, is sufficient to shift the rock into another order, .60 being the dividing ratio. The probable cause is that the ratio present in the slide is not quite normal, the quartz not being equably distributed through the rock.

Syenite. The great amount of differentiation shown by the rock of the syenite bathylith has already been noted. Analyses of a considerable number of these have been already published, but there were yet lacking those of the more basic and more acid phases, and moreover the red syenites which occur in association with the granitic syenite had not been carefully investigated.

The specimen of basic syenite (12-1-6) selected for investigation, was collected a little over a mile n.n.w. from Raquette falls. It is a rather evenly granular, gneissoid rock, feldspar phenocrysts being few and of small size. The thin section shows augite and hypersthene in the parallel growths which are so characteristic of this rock, hornblende, magnetite, light colored titanite, apatite, patchy, vermicular garnet, a little quartz, a little pyrite, and feldspar which is in part microperthite and in part oligoclase-andesin. The mode of the rock, by Rosiwal's method, is as follows:

Mode of basic syenite (12-1-6)

	Units measured	Sp. Gr.		Units by weight		% weight
Feldspar	748	x 2.64	=	1975	=	56.12
Quartz	38	x 2.65	=	101	=	2.87
Hornblende	103	x 3.3	=	340	=	9.65
Augite	123	x 3.3	=	406	=	11.54
Hypersthene	111	x 3.35	=	372	=	10.57
Magnetite	44	x 5.25	=	231	=	6.57
Garnet	7	x 3.85	=	27	=	0.77
Apatite	15	x 3.2	=	48	=	1.37
Titanite	4	x 3.5	=	14	=	0.40
Pyrite	1	x 5	=	5	=	0.14
Total	1194			3519		100.00

Chemical composition and norm of basic syenite (12-1-6)[1]

	Chem. comp.	Mol. ratio.	Or.	Ab.	An.	Di.	Hy.	Mag.	Ap.	Ti.	Qz.	Py.
SiO_2	54.10	.902	.196	.368	.154	.026	.107	....	....	.002	.048	....
Al_2O_3	17.45	.171	.033	.061	.077	....	....	....	....	....	....	....
Fe_2O_3	4.52	.028	....	....	....	....	....	.028	....	....	....	.002
FeO	6.47	.090	....	....	....	.007	.050	.028	....	.002	....	....
MgO	2.33	.058	....	....	....	.006	.052	....	....	....	....	....
CaO	6.17	.110	....	....	.076	.013	....	....	.021	....	....	....
Na_2O	3.81	.061	....	.061	....	....	....	....	....	....	....	....
K_2O	3.06	.033	.033	....	....	....	....	....	....	....	....	....
H_2O+	0.48	....	....	....	....	....	....	....	....	....	....	....
H_2O-	0.09	....	....	....	....	....	....	....	....	....	....	....
TiO_2	0.19	.002	....	....	....	....	....	....	....	.002	....	....
P_2O_5	0.88	.006	....	....	....	....	....	....	.006	....	....	....
F	0.05	.003	....	....	....	....	....	....	.003	....	....	....
S	0.14	.004	....	....	....	....	....	....	....	....	....	.004
MnO	0.35	.005	....	....	....	....	.005	....	....	....	....	....
BaO	0.10	.001	....	....	.001	....	....	....	....	....	....	....
Total	100.19	....	.033	.061	.077	.026	.107	.028	.006	.002	.048	.002
	.06											
	100.13	ZrO₂, Cr₂O₃ and Cl absent										

Or.	18.13	74.59
Ab.	32.17	
An.	21.43	
Qz.	2.86	
Di.	3.05	24.83
Hy.	12.50	
Mt.	6.57	
Ti.	0.36	
Ap.	2.09	
Py.	0.26	
Total.	99.42	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{74.59}{24.83} = 3.00 = \text{II} =$ dosalane

Order, $\frac{Q}{F} \frac{2.86}{71.73} = .04 = 5$, germanare

Rang, $\frac{Na_2O' + K_2O'}{CaO'} = \frac{940}{1102} = .85 = 3$, andase

Subrang, $\frac{K_2O'}{Na_2O'} \frac{32}{61} = .53 = 4$, andose, but near shoshonose

As usual with these rocks the ferrous iron determination was unsatisfactory from some cause not yet clear, the result of the analysis showing 10.96 FeO out of a total iron of 10.99. In this case there is a possibility that the pyrite may be accountable for the discrepancy, but it is very unlikely that this is the case since the trouble is constant in the rock group and the pyrite is occasional. The microscopic analysis showed a considerable percentage of magnetite present, the amount of which was checked by separating the magnetite from a certain portion of the rock, so that the result

1 Sp. Gr. 2.964 at 18°. Analyst, E. W. Morley.

is reasonably accurate. The ferric iron given in the analysis is that in the magnetite as thus determined. It is certainly somewhat low since there is a strong probability of some ferric iron in the femic minerals but there is an equally strong probability that the amount is trifling, so that reasonable confidence is felt that the figures given are close to the truth.

Since the same error in the iron determination is found in the syenite analyses previously published, and since it is also desirable to consider them with respect to their position in the new rock classification, microscopic analyses were also made of them and the figures for iron changed so far as determinations of the amount of magnetite present would permit. As thus modified the analyses should supersede those already published [N. Y. State Mus. Bul. 95. p. 331–32].

	1	2	3	4	5	6	7	8
SiO_2	54.10	57.00	59.70	61.01	63.45	65.65	66.72	68.5
Al_2O_3	17.45	16.01	19.52	15.36	18.38	16.84	16.15	14.69
Fe_2O_3	4.52	10.30	1.89	2.08	1.09	4.01	1.23	1.34
FeO	6.47		4.92	7.77	2.69		2.10	3.25
MgO	2.33	1.62	.78	.78	.35	.13	.73	.26
CaO	6.17	6.20	3.36	4.05	3.06	2.47	2.30	2.20
Na_2O	3.81	4.35	5.31	3.68	5.06	5.27	4.36	3.50
K_2O	3.00	3.53	4.14	3.90	5.15	5.04	5.66	5.90
H_2O +	0.48	.15	.52	.49	.30	.30	.77	.40
H_2O —	0.99							
TiO_2	0.19	......	......	......	.07	......	......	......
P_2O_5	0.88	......	......	......	......	......	......	.03
Cl	......	......	......	......	......	......	......	......
F	0.05	......	......	......	......	......	......	......
S	0.14	......	......	......	......	......	......	......
MnO	0.35	......	.09	.08	trace	......	.07	.10
BaO	0.10	......	......	......	.13	......	......	.05
Total	100.19	99.16	100.23	100.10	99.73	99.71	100.18	100.22
	.06	......	......	......	......	......	......	......
	100.13	......	......	......	......	......	......	......
Sp. gr.	2.964	......	2.674	......	2.719	......	......	......

1 Basic syenite (andose) from near Raquette falls, analysis by E. W. Morley.

2 Basic syenite from Natural Bridge, Diana, Lewis co. C. H. Smyth jr, Geol. Soc. Am. Bul. 6:274.

3 Augite syenite (laurvikose), road from Tupper lake to Wawbeck. N. Y. State Geol. 20th An. Rep't. 1902. p. 169.

4 Augite syenite (harzose), by N. Y. C. & H. R. Railroad. $3\frac{1}{2}$ miles north of Tupper Lake Junction. *Op. cit.* p. r69.

5 Augite syenite (pulaskose), Loon lake, Franklin co. Geol. Soc. Am. Bul. 10:177–92.

6 Augite syenite, near Harrisville, Diana, Lewis co. C. H. Smyth jr, Geol. Soc. Am. Bul. 6:271–74.

7 Augite syenite (toscanose), Little Falls, Herkimer co. *Op. cit.* p. r69.

8 Quartz syenite (toscanose), N. Y. & Ottawa Railroad. $2\frac{1}{2}$ miles south of Willis pond, Altamont, Franklin co. *Op. cit.* p. r69.

All analyses except 2 and 6 by E. W. Morley.

This series of analyses gives an excellent representation of the amount of differentiation in the Tupper syenite bathylith. To be sure analyses 2, 5, 6 and 7 are from rocks from other localities, but 5, 6 and 7 are representative of the normal character of the rock at all localities, at Tupper lake as well as at other points, and 2 is a distinct intermediate stage between 1 and 3 which could certainly be duplicated there. These are all green syenites; analyses of the red syenites will follow. Only analyses of the red granitic phases fail.

Of the six analyses which are sufficiently complete to enable the placing of the rock in the new system, it will be seen that four are persalanes and two dosalanes, that five different orders are represented and five different subrangs, altogether showing a large amount of differentiation for a bathylith of no great size. While it is possible that somewhat more acid phases may be present it is held to be very unlikely that any of the rocks of the bathylith run over 70% of silica.

It is to be noted that all of the rock has experienced considerable metamorphism, having a granular structure which has been produced by mashing and recrystallization, and that the original structure was granitic and somewhat porphyritic. The rock of analysis 1 would therefore be properly described as a hornblendic pyroxene-granophyro-andose.

The rock of analysis 3 is from a large dike of syenite which cuts gabbroid anorthosite. It is a granular, quite porphyritic rock composed of microperthite, augite, hornblende, garnet, magnetite and quartz, the garnet and quartz mainly in corrosion rims between the magnetite and feldspar. Its norm is as follows:

Chemical composition and norm of hornblendic augite-laurvikose

	Chem. comp.	Mol. ratio	Or.	Ab.	An.	Co.	Hy.	Mt.	Qz.
SiO_2	59.70	.995	.263	.514	.123	......	.076	......	.019
Al_2O_3	19.52	.191	.044	.086	.061	.0004	......	......	......
Fe_2O_3	1.89	.012	......	......	......	......	......	.012	......
FeO	4.92	.068	......	......	......	......	.057	.012	......
MgO	.78	.019	......	......	......	......	.019	......	......
CaO	3.36	.060	......	......	.060	......	......	......	......
Na_2O	5.31	.086	......	.086	......	......	......	......	......
K_2O	4.14	.044	.044	......	......	......	......	......	......
H_2O	0.52	......	......	......	......	......	......	......	......
MnO	0.09	.001	......	......	.001	......	......	......	......
Total	100.23	......	.044	.086	.061	......	.076	.012	.019

Or.	24.40	
Ab.	44.85	
An.	17.04	87.49
Co.	0.04	
Qz.	1.16	
Mt.	2.73	12.13
Hy.	9.40	
Total	99.62	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{87.49}{12.13} = 7.21 = 1$, persalane

Order, $\frac{Q}{F} = \frac{1.16}{86.33} = .013 = 5$, canadare

Rang, $\frac{K_2O' + Na_2O'}{CaO'} = \frac{1295}{613} = 2.1 = 2$, pulaskase

Subrang, $\frac{K_2O'}{Na_2O'} = \frac{44}{86} = .51 = 4$, laurvikose

The rock is close to the border between classes I and II, and also between subrangs 3 and 4, so that it is near both pulaskose and akerose, more especially the latter.

The rock of analysis 4 has the following mode

	Units measured	Sp. Gr.		Units by weight		% weight
Microperthite	1546	x 2.6	=	4011	=	58.07
Plagioclase	159	x 2.63	=	417	=	6.04
Quartz	247	x 2.65	=	654	=	9.47
Augite	143	x 3.3	=	472	=	6.83
Bronzite	63	x 3.3	=	208	=	3.01
Hornblende	127	x 3.2	=	406	=	6.01
Garnet	84	x 3.7	=	311	=	4.50
Magnetite	57	x 5.25	=	299	=	4.33
Apatite	22	x 3.2	=	70	=	1.01
Titanite	6	x 3.5	=	21	=	0.33
Pyrite	6	x 5.0	=	30	=	0.43
Zircon	2	x 4.5	=	9	=	0.13
Total	2462			6908		100.16

Also biotite and allanite 1 each.

Though slightly more acid than the previous rock it has a much larger percentage of femic and alferric minerals. It is also noteworthy in the number of different minerals shown in the slide, 14 being present. The magnetite would yield 2.98% of Fe_2O_3, and this is substituted for the small amount which the chemical analysis yielded.

Norm of hornblendic pyroxene-harzose (analysis 4)

	Chem. comp.	Mol. ratio	Or.	Ab.	An.	Hy.	Di.	Mt.	Ti.	Qz.
SiO_2	61.01	1.017	.248	.356	.100	.087	.043	....	.001	.181
Al_2O_3	15.36	.151	.041	.059	.050	....	....	....	....	....
Fe_2O_3	2.98	.019	....	....	....	....	....	.019	....	....
FeO	7.77	.108	....	....	....	.072	.017	.019	....	....
MgO	.78	.019	....	....	....	.015	.004	....	....	....
CaO	4.05	.072	....	....	.050	....	.021	....	.001	....
Na_2O	3.68	.059	....	.059	....	....	....	....	....	....
K_2O	3.90	.041	.041	....	....	....	....	....	....	....
H_2O	0.49	....	....	....	....	....	....	....	....	....
MnO	0.08	.001	....	....	....	....	.001	....	....	....
Total	100.10	......	.041	.059	.050	.087	.043	.019	.001	.181

Or.	23.02	78.90
Ab.	31.13	
An.	13.89	
Qz.	10.86	
Mt.	4.32	20.74
Hy.	11.03	
Di.	5.22	
Ti.	0.17	
Total	99.64	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{78.90}{20.74} = 3.81 = \text{II}$, dosalane

Order, $\frac{Q}{F} = \frac{10.86}{68.04} = 0.16 = 4$, austrare

Rang, $\frac{K_2O' + Na_2O'}{CaO'} = \frac{100}{72} = 1.4 = 3$, tonalase

Subrang, $\frac{K_2O'}{Na_2O'} = \frac{41}{59} = .7 = 3$, harzose

The rock is close to the division line between orders 4 and 5, so that it is a harzose very close to shoshonose.

The slides of the type syenite from Loon lake, analysis 5, have been mislaid and could not be found, so that the readjustment of the iron percentages had to be based wholly on separation of magnetite from a weighed amount of crushed rock by heavy solutions and magnet. The result gave 1.58% of magnetite, or 1.09% of Fe_2O_3, which is certainly much more nearly correct than the .42% of the original analysis. Its norm would thus become:

Or.....	30.41	91.42
Al.....	42.76	
An....	12.20	
Qz.....	6.05	
Mt....	1.58	7.94
Di.....	2.00	
Hy....	4.19	
Ti.....	0.17	
Total	99.36	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{91.42}{7.94} = 11.5 = 1$, persalane

Order, $\frac{Q}{F} = \frac{6.05}{85.37} = .07 = 5$, canadare

Rang, $\frac{K_2O' + Na_2O'}{CaO'} = \frac{136}{52} = 2.6 = 2$, pulaskase

Subrang, $\frac{K_2O'}{Na_2O'} = \frac{55}{81} = .68 = 3$, pulaskose

The rock falls close to the boundary between subrangs 3 and 4, or is close to laurvikose, showing thus its close relationship with the considerably more basic rock of analysis 3.

The Little Falls rock (analysis 7) has beautiful cataclastic structure with the production of much finely granular feldspar and quartz which can not with certainty be distinguished in the thin section. The quartz and feldspar had therefore to be measured together in the determination of the mode.

Mode of Little Falls syenite (toscanose) analysis 7

	Units measured	Sp. Gr.		Units by weight		% weight
Quartz and feldspar..............	2852	x 2.61	=	7444	=	87.28
Hornblende..........................	189	x 3.2	=	604	=	7.08
Pyroxene...........................	50	x 3.3	=	165	=	1.94
Magnetite...........................	30	x 5.25	=	158	=	1.85
Biotite...............................	20	x 3.	=	60	=	0.70
Apatite..............................	10	x 3.2	=	32	=	0.37
Titanite.............................	11	x 3.5	=	38	=	0.44
Zircon...............................	3	x 4.5	=	13	=	0.14
Pyrite...............................	3	x 5.	=	15	=	0.18
Total.............................	3168			8529		99.98

Norm of Little Falls syenite

Or.....	33.42	91.51
Ab....	36.84	
An....	7.78	
Qz.....	13.47	
Mt....	1.85	8.04
Di.....	2.23	
Hy....	3.59	
Ap....	0.37	
Total	99.55	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{91.51}{8.04} = 11.37 = 1$, persalane

Order, $\frac{Q}{F} = \frac{13.47}{78.04} = .17 = 4$, britannare

Rang, $\frac{K_2O' + Na_2O'}{CaO'} = \frac{136}{52} = 2.6 = 2$, toscanase

Subrang, $\frac{K_2O'}{Na_2O'} = \frac{547}{816} = .67 = 3$, toscanose

The quartz-feldspar ratio is nearly low enough to throw the rock into order 5 instead of 4, so that it is a toscanose close to pulaskose.

The mode of the rock of analysis 8 showed 1.86% of Fe_2O_3, and the original analysis was corrected on this basis, so far as the iron values are concerned. The norm, and position of the rock in the new classification are as follows:

Norm of pyroxenic hornblende-toscanose (analysis 8)

	Chem. comp.	Mol. ratio.	Or.	Ab.	An.	Di.	Hy.	Mt.	Ap.	Qz.
SiO_2	68.50	1.142	.376	.339	.050	.028	.031			.318
Al_2O_3	14.69	.144	.063	.056	.025					
Fe_2O_3	1.34	.008						.008		
FeO	3.25	.045				.012	.025	.008		
MgO	0.26	.007				.002	.005			
CaO	2.20	.039			.025	.014			.0007	
Na_2O	3.50	.056		.056						
K_2O	5.90	.063	.063							
H_2O	0.40									
P_2O_5	0.03	.0002							.0002	
MnO	0.10	.001					.001			
BaO	0.05									
Total	100.22		.063	.056	.025	.028	.031	.008		.318

Or.	34.81	90.43
Ab.	29.61	
An.	6.92	
Qz.	19.09	
Hy.	3.95	9.29
Di.	3.41	
Ap.	0.07	
Mt.	1.86	
Total	99.72	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{90.43}{9.29} = 9.8 = 1$, persalane

Order, $\frac{Q}{F} = \frac{19.09}{71.34} = .27 = 4$, britannare

Rang, $\frac{K_2O' + Na_2O'}{CaO} = \frac{119}{39} = 3.1 = 2$, toscanase

Subrang, $\frac{K_2O'}{Na_2O'} = \frac{63}{56} = 1.13 = 3$, toscanose

Because of its greater acidity this rock is a fairly normal toscanose, instead of being on the pulaskose border, the quartz being to the feldspar as 1 : 4 instead of 1 : 6 as in the previous case.

Red syenites. It has been shown that on the southern margin of the Tupper syenite a considerable mass of red syenites and granitic syenites occurs, showing apparent gradations into the normal syenite, though it is not yet definitely established whether it is a differentiate from that or a separate intrusion. The rock is usually evenly granular and gneissoid, though often showing small, porphyritic feldspars, but it runs into coarsely porphyritic varieties. The tendency of the quartz to assume the leaf, or spindle types is even more pronounced than in the green syenite. The analyses

show very little difference in composition between the two. Hornblende is more prominent than pyroxene in the red rock while the reverse is true in the green. Only one analysis has been made of the red rocks, but the rock lends itself readily to microscopic analysis and these have been used to supplement the other. As a test of the matter a microscopic analysis of the rock later analyzed was made and calculated. The feldspars are easily distinguished from the quartz, and judging from those in the other syenites were assumed to consist of orthoclase and plagioclase in the ratio 3 : 4, and the plagioclase was assumed to be $Ab_4\ An_1$. The hornblende was assumed to have the composition of the hornblende from the quartz-monzonite from Mt Hoffman, Cal.[1]

Mode of red syenite (granophyro-hornblende monzonose) from the north boundary of Litchfield park (10-B-2)

	Units measured	Sp. Gr.		Units by weight		% weight
Microperthite	793	x 2.6	=	2062	=	54.65
Plagioclase	320	x 2.6	=	832	=	22.02
Quartz	146	x 2.65	=	387	=	10.24
Hornblende	117	x 3.3	=	386	=	10.22
Magnetite	15	x 5.2	=	78	=	2.07
Apatite	7	x 3.2	=	22	=	0.58
Zircon	2	x 4.3	=	9	=	0.22
Total	1400			3776		100.00

Composition calculated from mode

	Qz.	Orth.	Alb.	Anor.	Horn.	Mag.	Apat.	Zirc.	Total
SiO_2	10.24	21.27	24.17	3.79	5.05	......	......	0.07	64.59
Al_2O_3	......	6.01	6.79	3.26	0.75	......	......	......	16.81
Fe_2O_3	......	......	......	......	0.51	1.43	......	......	1.94
FeO	......	......	......	......	1.12	0.64	......	......	1.76
MgO	......	......	......	......	1.39	......	......	......	1.39
CaO	......	......	......	1.78	1.27	......	0.32	......	3.37
Na_2O	......	......	4.14	......	0.08	......	......	......	4.22
K_2O	......	5.51	......	......	0.05	......	......	......	5.56
P_2O_5	......	......	......	......	......	......	0.24	......	0.24
F	......	......	......	......	......	......	0.02	......	0.02
ZrO_2	......	......	......	......	......	......	......	0.15	0.15
Total	10.24	32.79	35.10	8.83	10.22	2.07	0.58	0.22	100.05

1 U. S. Geol. Sur. Bul. 168, p. 208.

Analysis and norm of red syenite (monzonose), 10-B-2[1]

	Chem. comp.	Mol. ratio.	Or.	Ab.	An.	Di.	Hy.	Mt.	Ti.	Ap.	Qz.
SiO_2	62.85	1.047	.350	.396	.081	.028	.048	....	.001	....	.143
Al_2O_3	16.80	.165	.058	.066	.040	....	....	....	....	....	....
Fe_2O_3	2.96	.018	....	....	....	....	....	.018	....	....	....
FeO	2.89	.040	....	....	....	.006	.016	.018	....	....	....
MgO	1.48	.037	....	....	....	.008	.029	....	....	....	....
CaO	3.24	.058	....	....	.040	.014	....	....	.001	.003	....
Na_2O	4.09	.066	....	.066	....	....	....	....	....	....	....
K_2O	5.49	.058	.058	....	....	....	....	....	....	....	....
H_2O+	0.24	....	....	....	....	....	....	....	....	....	....
H_2O-	0.13	....	....	....	....	....	....	....	....	....	....
TiO_2	0.09	.001	....	....	....	....	....	....	.001	....	....
P_2O_5	0.13	.001	....	....	....	....	....	....	....	.001	....
F	0.01	....	....	....	....	....	....	....	....	....	....
S	0.02	....	....	....	....	....	....	....	....	....	....
MnO	0.21	.003	....	....	....	....	.003	....	....	....	....
BaO	0.06	....	....	....	....	....	....	....	....	....	....
Total	100.69	.....	.058	.066	.040	.028	.048	.018	.001	.001	.143

Or.	32.47	86.87
Ab.	34.58	
An.	11.20	
Qz.	8.62	
Di.	3.19	13.43
Hy.	5.42	
Mt.	4.29	
Ap.	0.31	
Ti.	0.22	
Total	100.30	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{86.87}{13.43} = 6.47 = 11$, dosalane

Order, $\frac{Q}{F} = \frac{8.62}{78.25} = .11 = 5$, germanare

Rang, $\frac{K_2O' + Na_2O'}{CaO'} = \frac{124}{58} = 2.1 = 2$, monzonase

Subrang, $\frac{K_2O'}{Na_2O'} = \frac{59}{66} = .9 = 3$, monzonose

On the border between classes I and II, hence close to pulaskose.

A comparison of the two analyses shows a reasonably close agreement in all respects, and indicates that microscopic analysis furnishes a means of quite accurate determination of the composition of these rocks. It shows that the feldspars have closely the assumed composition, and that the hornblende is probably lower in silica and higher in iron than the Californian hornblende used in the calculation. The norm calculated from the result of the microscopic analysis would closely agree with the other, and serve equally for classifying the rock.

A comparison of the analysis with those of the green syenites shows a close agreement, the main differences being the different ratio between the iron oxids and the lower magnesia of the green

[1] Sp. Gr. 2.735 at 18°. E. W. Morley, analyst.

rocks. The field evidence of close relationship between the rocks thus receives forcible corroboration.

One half mile east of the locality from which the previous rock was obtained, on the north line of Litchfield park, occurs a beautiful, coarse red syenite which differs from the last in holding little or no quartz. Its calculation follows:

Mode of red syenite (monzonose) 10-C-1

	Units measured	Sp. Gr.		Units by weight		% weight
Microperthite	1463	x 2.6	=	3803	=	65.72
Plagioclase	299	x 2.63	=	786	=	13.58
Hornblende	267	x 3.2	=	854	=	14.76
Quartz	62	x 2.65	=	164	=	2.84
Magnetite	32	x 5.25	=	168	=	2.90
Apatite	1	x 3.2	=	3	=	0.05
Zircon	2	x 4.3	=	9	=	0.15
Total	2126			5787		100.00

Composition and norm calculated from mode

	Qz.	Orth.	Alb.	Anor.	Horn.	Mag.	Apat.	Zirc.	Total
SiO_2	2.84	22.03	24.90	3.91	7.29			0.05	61.0
Al_2O_3		6.24	7.06	3.33	1.08				17.7
Fe_2O_3					0.75	2.00			2.7
FeO					1.64	0.90			2.5
MgO					2.01				2.0
CaO				1.82	1.83		0.03		3.6
Na_2O			4.29		0.11				4.4
K_2O		5.72			0.05				5.7
P_2O_5							0.02		0.0
ZrO_2								0.10	0.1
Total	2.84	33.99	36.25	9.06	14.76	2.90	0.05	0.15	100.0

The calculated norm is:

Or.	Ab.	An.	Di.	Hy.	Mt.	Qz.
34.15	37.20	11.40	5.53	4.74	3.99	2.82

$$\text{Class, } \frac{\text{Sal.}}{\text{Fem.}} = \frac{85.57}{14.26} = 6.0 = \text{I}, \text{ dosalane}$$

$$\text{Order, } \frac{\text{Q}}{\text{F}} = \frac{2.82}{82.75} = .034 = 5, \text{ germanare}$$

$$\text{Rang, } \frac{K_2O' + Na_2O'}{CaO'} = \frac{132}{66} = 2, \text{ monzonase}$$

$$\text{Subrang, } \frac{K_2O'}{Na_2O'} = \frac{61}{71} = .86 = 3, \text{ monzonose}$$

Judging by the previous case the silica and iron are a trifle out of the way, the former too high and the latter too low. It might be legitimate to modify the analysis proportionately with the differ-

ences shown in the two analyses of the previous rock, but these would affect it but slightly, and since the trouble with the previous analysis may be mainly owing to the fact that the normal amount of magnetite did not get into the slide, rather than because of difference in the composition of the hornblende, the change might not be an improvement. The analysis is confidently regarded as an accurate expression of the composition of the rock, which is somewhat more basic than the previous one.

As a sample of the more granitic syenite of this group a rock was selected which outcrops on the road from the Litchfield gate to the boathouse on Tupper lake. It is quite similar to the rock of which the lodge and gate are built and it outcrops over a wide area within the park where it seems to shade into the green syenite. While some portions of the mass may be even more acid than this is, none is greatly more so.

Mode of red, granitic syenite (toscanose), 869

	Units measured	Sp. Gr.		Units by weight		% weight
Microperthite	1907	x 2.6	=	4958	=	67.20
Plagioclase	281	x 2.63	=	739	=	10.01
Quartz	452	x 2.65	=	1198	=	16.24
Hornblende	107	x 3.2	=	342	=	4.63
Magnetite	21	x 5.25	=	110	=	1.49
Biotite	3	x 3.0	=	9	=	0.12
Apatite	6	x 3.2	=	19	=	0.25
Zircon	1	x 4.5	=	4	=	0.05
Total	2778			7379		99.99

Composition and norm calculated from mode

	Qz.	Orth.	Alb.	Anor.	Horn.	Biot.	Mag.	Apat.	Zir.	Total
SiO_2	16.24	21.47	24.26	3.82	2.29	0.05	....	......	0.02	68.15
Al_2O_3	.....	6.06	6.86	3.25	0.34	0.02	....	......	....	16.53
Fe_2O_3	.....	.....	.....	......	0.23	0.01	1.02	......	....	1.26
FeO	.....	.....	.....	......	0.51	0.02	0.47	......	....	1.00
MgO	.....	.....	.....	......	0.63	0.01	....	......	....	0.64
CaO	.....	.....	.....	1.78	0.57	......	....	0.13	....	2.48
Na_2O	.....	.....	4.18	......	0.04	......	....	......	....	4.22
K_2O	.....	5.56	.....	......	0.02	0.01	....	......	....	5.59
P_2O_5	.....	.....	.....	......	......	......	....	0.10	....	0.10
F	.....	.....	.....	......	......	......	....	0.02	....	0.02
ZrO_2	.....	.....	.....	......	......	......	....	......	0.03	0.03
Total	16.24	33.09	35.30	8.85	4.63	0.12	1.49	0.25	0.05	100.02

From which the norm is:

Or.	Ab.	An.	Mt.	Di.	Hy.	Qz.	Total
33.08	35.32	9.79	1.84	2.03	1.40	16.36	99.82

$$\text{Class, } \frac{\text{Sal.}}{\text{Fem.}} = \frac{94.55}{5.27} = 18 = 1, \text{ persalane}$$

$$\text{Order, } \frac{Q}{F} = \frac{16.36}{78.19} = .21 = 4, \text{ britannare}$$

$$\text{Rang, } \frac{K_2O' + Na_2O'}{CaO'} = \frac{127}{44} = 2.9 = 2, \text{ toscanase}$$

$$\text{Subrang, } \frac{K_2O'}{Na_2O'} = \frac{59}{67} = .88 = 3, \text{ toscanose}$$

A coarse, red, porphyritic syenite which is very quartzose, composes the steep cliffs on the south end of the big ridge known locally as Follensby mountain, which lies southwest of Follensby pond. Its mineralogy is the same as the previous rocks except for holding augite in addition to hornblende. In the calculation the augite was assumed to have the composition of the diopside from the laurvikite near Laurvik, Norway.[1] While that is more basic it is otherwise a similar rock to this, and the augite has the same character as that in the more basic syenites which closely correspond to Brögger's rock. For the sake of brevity the details of the calculation are omitted.

Mode, composition and norm of toscanose (10-D-3)

Units measured		% weight	Composition		Norm	
Microperthite	1760	59.50	SiO_2	74.17	Or	26.80
Quartz	898	30.93	Al_2O_3	13.30	Ab	28.98
Plagioclase	72	2.47	Fe_2O_3	0.26	An	7.48
Hornblende	96	4.12	FeO	0.77	Di	3.27
Augite	67	2.87	MgO	0.81	Hy	1.68
Magnetite	1	0.07	CaO	2.34	Mt	0.37
Apatite	1	0.04	Na_2O	3.43	Qz	31.64
			K_2O	4.53		
			P_2O_5	0.02		
Total	2895	100.00		99.63		100.22

$$\text{Class, } \frac{\text{Sal.}}{\text{Fem.}} = \frac{95.90}{5.22} = 19 = 1, \text{ persalane}$$

$$\text{Order, } \frac{Q}{F} = \frac{31.64}{63.26} = .5 = 4, \text{ britannare}$$

$$\text{Rang, } \frac{K_2O' + Na_2O'}{CaO'} = \frac{103}{42} = 2.4 = 2, \text{ toscanase}$$

$$\text{Subrang, } \frac{K_2O'}{Na_2O'} = \frac{48}{55} = .87 = 3, \text{ toscanose}$$

1 Brögger, Eruptivgest. Kristianageb. 3:23.

This is the most acid of any rock yet analyzed occurring as a part of the general syenite mass and is an unquestionable granite. It is quite close to order 3, and though not quite so acid much resembles the Morris granite in composition, except for the higher lime. For convenience in comparison the four analyses, and that of the Morris granite are here placed side by side.

	I	II	III	IV	V
SiO_2	61.02	62.85	68.15	74.17	76.41
Al_2O_3	17.71	16.80	16.53	13.30	12.41
Fe_2O_3	2.75	2.96	1.26	0.26	1.01
FeO	2.54	2.89	1.00	0.77	0.50
MgO	2.01	1.48	0.64	0.81	0.46
CaO	3.68	3.24	2.48	2.34	0.78
Na_2O	4.40	4.09	4.22	3.43	3.34
K_2O	5.77	5.49	5.59	4.53	4.33
H_2O+	......	0.24	......	......	0.34
H_2O-	......	0.13	......	......	0.13
TiO_2	......	0.09	......	......	0.03
P_2O_5	0.02	0.13	0.10	0.02	trace
F	......	0.01	0.02	......	0.01
S	......	0.02	......	......	0.01
ZrO_2	0.10	trace	0.03	......	0.02
MnO	......	0.21	......	......	0.06
BaO	......	0.06	......	......	trace
Total	100.00	100.69	100.02	99.63	99.84

I Syenite, (monzonose) 10-C-1, microscopic analysis.
II Syenite, (monzonose) 10-B-2, E. W. Morley, analyst.
III Quartz syenite (toscanose) 869, microscopic analysis.
IV Granite (toscanose) 10-D-3, microscopic analysis.
V Morris granite (alaskose) 15-A-3, E. W. Morley, analyst.

Grenville igneous rocks. There occurs in frequent association with the Grenville sediments of the quadrangle, especially with the quartz gneisses, a rock which is not especially gneissoid, has an igneous look, and also at times appears to show igneous contacts against the quartz schists, though these are so disturbed that it is difficult to be certain in the matter. The texture is fine grained granitic, with abundant glittering feldspar cleavages, and the color is a grayish white, with a smack of a flesh-colored tinge. It is a fairly easy rock to recognize, though difficult to describe with exactness. If an igneous rock it is certainly of much greater antiquity than the big intrusions, and to class it with the Grenville, with which alone it occurs, seems the obvious course. Its chemical composition is as follows:

Composition and norm of Grenville quartz-syenite (dellenose) 1-M-5 from near Lake Catlin

	Chem. comp.	Mol. ratio.	Or.	Ab.	An.	Di.	Wo.	Mt.	Ti.	Py.	Qz.
SiO_2	68.66	.144	.470	.100	.028	.041	.009		.002		.386
Al_2O_3	12.98	.127	80	33	14						
Fe_2O_3	2.89	.018						18			
FeO	1.26	.018						17		1	
MgO	0.76	.019				19					
CaO	2.63	.047			14	21	9		2		
Na_2O	2.05	.033		33							
K_2O	7.50	.080	80								
H_2O +	0.48										
H_2O −	0.09										
TiO_2	0.10	.002							2		
P_2O_5	0.07	.0005									
F	0.01										
S	0.08	.002								2	
MnO	0.24	.003				2		1			
BaO	0.07										
Total	99.96		.080	.033	.014	.041	.009	.018	.002		.386

Or.	44.37	88.86
Ab.	17.34	
An.	3.97	
Qz.	23.18	
Di.	4.50	10.39
Wol.	1.06	
Mt.	4.20	
Ti.	0.33	
Py.	0.15	
Ap.	0.15	
Total	99.25	

Class, $\frac{\text{Sal.}}{\text{Fem.}} = \frac{88.86}{10.39} = 8.5 = 1$, persalane

Order, $\frac{Q}{F} = \frac{23.18}{65.68} = .35 = 4$, britannare

Rang, $\frac{K_2O' + Na_2O'}{CaO'} = \frac{113}{47} = 2.4 = 2$, toscanase

Subrang, $\frac{K_2O'}{Na_2O'} = \frac{80}{33} = 2.4 = 2$, dellenose

E. W. Morley, analyst.

Chemically this rock is sharply distinguished from the syenites by the somewhat lower alumina and soda, and the high potash. The slide shows the feldspar to be mainly microcline, though with some microcline-microperthite and microperthite. It shows considerable quartz though by no means so much as the analysis indicates, and the dark colored minerals are augite and titanite, very little magnetite being present. The augite must therefore be high in iron. The character of the feldspar is quite different from that of the syenites, as indeed might be expected from the analysis, and this constitutes the main difference between this rock and the syenites. The augite must also be of quite different composition.

The analysis seems to warrant the conclusion that the rock is an igneous one, and if that be true the obvious differences between it and the eruptives previously described suggest a separation from them and likely an age difference.

Pyroxenic amphibolites, hornblende-andesin rocks with accessory augite, hypersthene and magnetite, occur in abundance associated with the distinctive Grenville rocks and have been described by all workers in districts where these rocks occur. They have been sometimes regarded as sediments, and sometimes as igneous rocks. The appended analysis is therefore of interest. It is the average of the three best analyses turned in by a class in quantitative analysis, and is therefore not of high grade. In consideration of the close supervision however, the close agreement between the three, and the general high character of the work done by the three men, it is thought to be worthy of respect, in consideration of the lack of better analyses. The rock was a Grenville amphibolite occurring south of Follensby pond and not far north of Moose creek.

SiO_2	50.71
Al_2O_3	18.75
Fe_2O_3	7.85
MgO	3.78
CaO	9.78
Na_2O	4.86
K_2O	2.42
H_2O+	1.13
H_2O-	0.06
MnO	0.25
Total	99.59

This is the composition of a diorite, or gabbro, and suggests, though it does not demonstrate, the igneous nature of the rock. If it be igneous it likewise is probably a much more ancient rock than the gabbros of the intrusions.

INDEX

MUSEUM BULLETIN 115

Geologic map of the Long Lake quadrangle